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Vehicle Body Stiffness Modeling Approach for Initial Conceptual Design

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A simple FE modeling technique is required to study body stiffness in the early stages of development. Because, if we can estimate the performance of the body structure in the early stage of development, it is expected to reduce the time of retrying developments caused by bad planning. We have developed a simple FE modeling method for body in white with the accuracy required in the early stages of development where details are undecided. In this paper, we introduce the modeling method of this simple FE model.

This model is a simple beams and shells model composed of beam elements, shell elements, and spring elements at the joint as shown in Figure 1(a). The total number of elements in this model is suppressed to about 1/100 of the detailed model, which leads to a significant reduction in analysis time.

Regarding the beam elements, only the main structural members are modeled on the beam elements. The extracted structural members are roughly divided for each part, and a representative cross section is extracted for each part. The number of parameters can be reduced by changing the cross section to a simple cross-sectional shape such as Box or Channel. The beam elements for each part are modeled with the same cross section.

About the shell elements, panels that affect the rigidity of the entire vehicle body structure, such as roofs and floor panels, are extracted and modeled as shell elements. For panels such as glass and roof panels whose out-of-plane deformation affects the stiffness of the entire structure, it is desirable to reproduce the actual shape as much as possible.

Regarding the spring element of the joint part, the joints of this model have been uniquely modeled and will be described in more detail. It is known that direct connection of beam elements at the junction where multiple structural members meet results in excessive stiffness. Therefore, spring-mass joint model is applied to the joint connected each structural member.

To create this spring-mass joint model, start by cutting out and analyzing the joint part of the detailed model. For the cut-out end of the detailed joint model, as shown Figure 1(b), mass is given to one end to be considered, and the remaining ends are constrained to perform eigenvalue analysis. By adjusting the mass, it is possible to find the mode on the weak-axis and the mode on the Strong-axis that are orthogonal to each other from the lower order side of the eigenvalue. The joint stiffness is calculated from each eigenvalue and the applied mass. Also, as shown Figure 1(c), from the mode vector of each eigenvalue, the rotation center of the displacement controlled by that mode is calculated.

For one cut-out end, prepare the following: the position of the center of rotation where the rotating spring is provided, local coordinates that define the axis of rotation of the rotating spring, a distance from the axis of rotation to the cut-out end, a spring constant of rotary spring calculated from joint stiffness, and length from the center of rotation to the end. Then it is possible to create a simple spring model for one end.

Simple spring modeling is performed for all the remaining ends in the same procedure. Connect each simple spring model created to the center of gravity of the joint with a rigid element. The opposite side of each spring model is connected to the cut end with a rigid element. Then one spring-mass joint model is completed as shown Figure 1(d).

As explained above, this spring-mass joint model is characterized by having an independent spring at each end. Therefore, engineers can easily perform a parameter study that multiplies the spring value at one end of this spring-mass joint model. Furthermore, it is possible to optimize the stiffness of the entire structure including the influence of the joint.

Finally, the accuracy of this simple beams and shells model was verified, and the results will be described. The frequency error of the eigenvalue analysis was within 10% in the first deformation mode to the 8th mode as shown Figure 2. In addition, modal assurance criterion got 0.7 or more in the 1st to 6th modes as shown Table 1. These results revealed that this model has enough accuracy in the early stages of development.

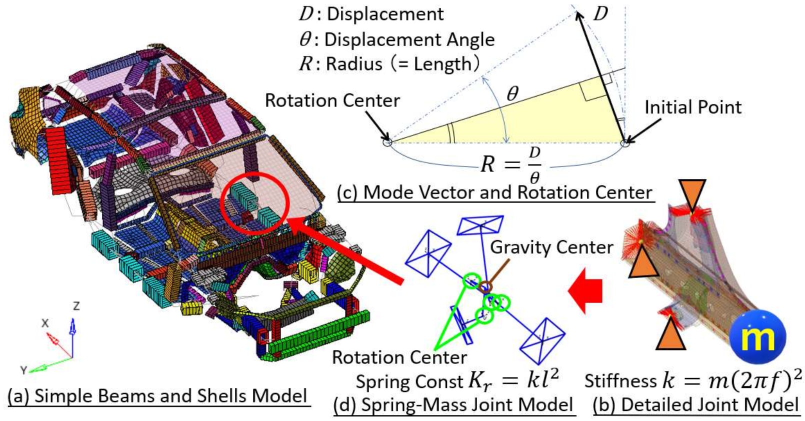

Fig.1 Simple Modeling Procedures

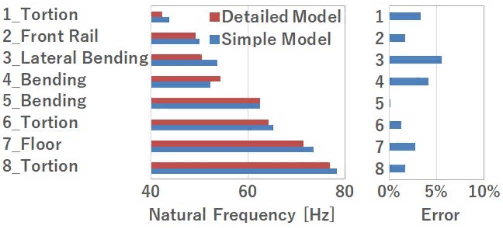

Fig.2 Eigenvalue Analysis Result

Table 1 Modal Assurance Criterion

		Simple Beams and Shells Model							
		1	2	3	4	5	6	7	8
Detailed Model	1	0.88	0	0	0	0	0.1	0	0.01
	2	0	0.86	0.08	0.01	0	0	0.09	0
	3	0	0.01	0.01	0.89	0	0.03	0	0.01
	4	0	0.01	0.83	0.01	0.02	0	0.05	0
	5	0	0.01	0.1	0	0.75	0	0.01	0
	6	0	0	0	0	0	0.71	0	0.02
	7	0	0	0	0	0.06	0	0.61	0
	8	0	0.03	0.01	0	0.03	0.06	0.06	0.35