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Extraction Method and Application of Unit Mode to Simplify NVH Problem

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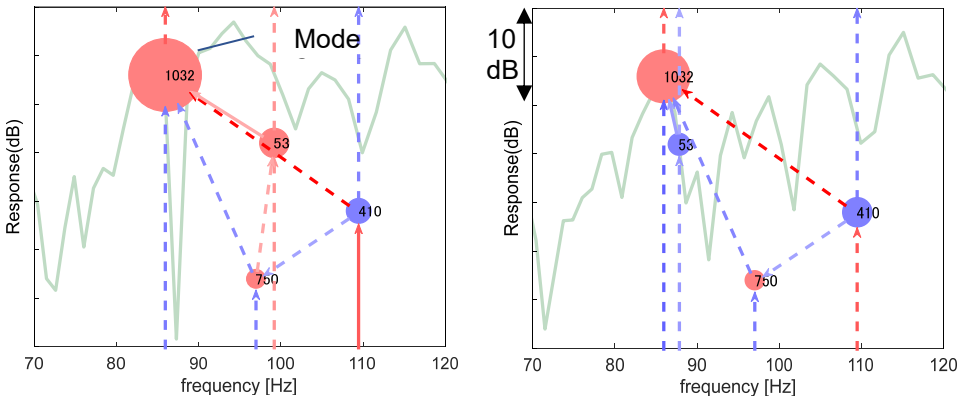
First of all, the definition of "Unit Mode" is a smallest unit component mode which has only one loop and cannot be decomposed any further. The resonance frequency of an unit mode is almost the same as that of whole system. An unit mode is a disassembly of eigenmodes of each part, and eigenmodes are obtained by assembling the unit modes. Applying the concept of unit mode to vibration, vibration is transmitted in order from the mode near the excitation point to the mode near the evaluation point, and the mechanism can be expressed as a power flow diagram using these unit modes. The path can be changed by shifting the eigenvalues.

The following is the outline to extract an unit mode. Oscillate the loop of the unit mode, then the unit mode is obtained from this operational response. However, since multiple modes may be mixed, try to separate the modes to keep the shape as simple as possible. In combination with the technique of automatically searching the loop of the mode, the unit mode, which is important as the vibration transmission path, is efficiently extracted.

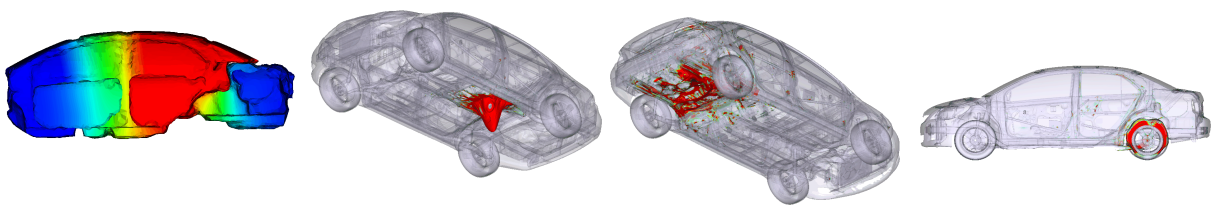
Now, road noise is simulated by calculating the sound pressure near the driver's outer ear when the four-wheel ground contact points of a vehicle FE model are individually oscillated with vertical enforced displacement excitation. Then 981 unit modes are extracted from 1471 structure eigenmodes, which is close to 70% of total. When the modes are examined, about 90% of them are extracted as one loop unit mode. Therefore, the concept is confirmed, which the vibration characteristics are made up of superpositions of simple-shaped unit modes. It is not necessary to solve simultaneous equations to predict the response change due to natural frequency shifts of the unit modes. If an enough number of the unit modes are obtained, the structural modification effect can be obtained instantly while ensuring practical accuracy.

As a result of examining the road noise reduction, it is found that the sound pressure around 90Hz generated by the left rear wheel excitation can be reduced by lowering the resonance frequency of a floor mode (53). The number in parentheses represents the mode number. The horizontal axis is frequency, and the figure shows that the vibration is transmitted from the bottom to the top, which is defined as the power flow. Fig. 1 shows the power flow before and after optimization in the 87-102Hz range that passes through the floor mode (53). Fig. 2 shows the mode shape that appears in the power flow diagram. Looking at Fig. 1 (a), the transmission path of the mode from the excitation point to the evaluation point can be confirmed in the order of tire (410) → spare tire pan (750) → floor (53) → fore-and-aft cavity resonance (1032). Comparing with Fig. 1 (b), it can be seen that the evaluation response is reduced by weakening this transmission path and changing in phase by separating the floor mode (53) from the spare tire pan mode (750).



(a) Original (b) Optimized

Fig.1 Power Flow（87−102Hz）



Mode1032 Mode53 Mode750 Mode410

Fig.2 Unit Mode Shape