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Evaluation of Parts Deformation Mode in Natural Vibration of Vehicle Body

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Many automotive parts are assembled from thin sheets. The application of thin-high-tensile steel sheet may cause a decrease in stiffness and natural frequency of vehicle body and chassis, resulting in deterioration of drivability and ride comfort, and increase in vibration and noise. Therefore, it is necessary to increase the stiffness of vehicle bodies made of thin steel sheets by improving the structure and joining methods. In particular, sheet bending deformation (out-of-plane deformation) is a deformation mode that has poor load transfer efficiency, and a structure that suppresses out-of-plane deformation is desirable.

This paper proposes a method for calculating the degree of sheet bending deformation in the natural vibration mode of vehicle body, which is important for evaluating the drivability, by referring to the previously proposed part b-factor analysis that calculates the degree of sheet bending deformation of parts in a thin sheet structure that deforms elastically. The ratio of the first-order sensitivity of the thickness to the eigenvalues of the structure with the density adjusted to keep the mass constant and the first-order sensitivity of the Young's modulus to the eigenvalues of the structure is defined as the part b-factor in the natural modes of vibration. Both of the above sensitivities can be obtained from eigenvalue analysis using the finite element method (FEM), and the part b-factor can be obtained for each natural vibration mode from FEM model, as shown in Fig.1. For all modes, the part b-factor ranges from 1 to 3, with values close to 1 or 3 indicating dominant in-plane deformation or dominant out-of-plane deformation, respectively.

Three parts with high Young's modulus sensitivity and high part b-factor calculated in the torsional mode are selected, and structural improvements are made to suppress out-of-plane deformation to estimate the change in natural frequency. Any improvements resulted in an increase in the natural frequency of torsion mode. It was also confirmed that the structural improvements reduced the part b-factor and improved the load transfer efficiency. In addition, the change in the torsional mode natural frequency due to thickening each part of 0.1 mm was calculated for all parts of vehicle body, and the comparison with the effect of the structural improvement is shown in Fig.2. The result of the structural improvements have higher efficiency than the maximum mass efficiency by thickening. This indicates that structural improvements based on sensitivity and part b-factor are more effective than the conventional thickness optimization based on thickness sensitivity analysis.

As shown in Fig.3, the sensitivities of each part show no or weak correlation among the natural vibration modes, while the part b-factors show a relatively strong correlation. This result suggests that the functioning parts change according to the natural vibration mode of the vehicle body, but the deformation modes of each part do not change. In other words, it can be presumed that the changes in the deformation mode of partial regions are small, and that changes in the magnitude of their deformation produce various deformation modes of vehicle body. Furthermore, it can be concluded that structural improvements of parts to increase the natural frequencies of a particular mode will also increase the natural frequencies of other modes.

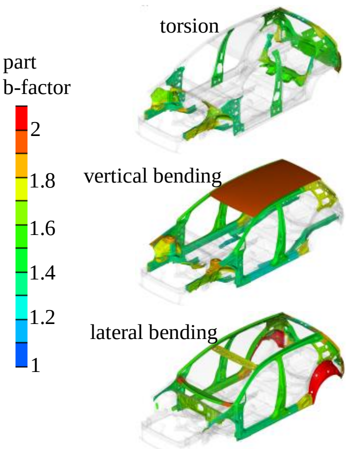

Fig.1 Distributions of part b-factor on torsion, vertical bending and lateral bending mode.

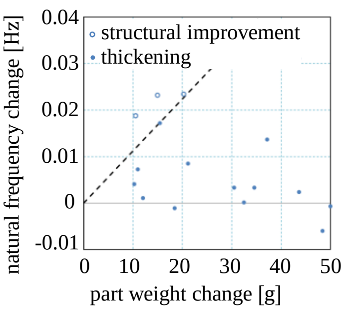

Fig.2 Comparison of the effects of structural improvement and thickening of each part on torsional natural frequency. The dash-line shows the maximum part-weight-efficiency of natural frequency change by thickening.

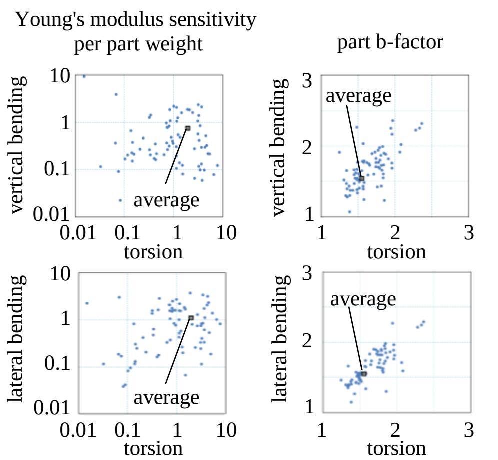

Fig.3 Correlation of Young's modulus sensitivity per part weight (left) and correlation of part b-factor (right) between each deformation mode.