Development of a Method for Predicting Underbody Stress from Road Interference

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Accurate prediction of underbody stress caused by road interference has become critical as vehicle ground clearance is reduced to improve aerodynamic performance and energy efficiency. In particular, battery electric vehicles often adopt lower ground clearance to accommodate large underfloor battery packs, thereby increasing the risk of contact between underbody components and irregular road surfaces. To ensure reliable design of underbody protection components, a simulation method capable of accurately predicting both stress magnitude and contact location during road interference is required.

This study develops an improved co-simulation approach that combines multibody dynamics (MBD) analysis with finite element method (FEM) structural analysis to predict underbody stress when a vehicle travels over severely deteriorated road surfaces. Initial co-simulation results exhibited noticeable discrepancies compared with vehicle test data, particularly in stress gradients and peak stress values during contact events. These discrepancies suggested that the overall stiffness of the simulation model was overestimated because major vehicle components, such as the body, were modeled as rigid bodies.

To clarify the dominant factor affecting prediction accuracy, the load transmission path during road interference was analyzed. The results revealed that the stiffness at the mounting points of the measurement device on the vehicle floor significantly affects the stress response. Although global bending and torsional deformation of the vehicle body were negligible under the test conditions, local deformation at the load application points had a pronounced influence on the measured stress.

Based on this finding, a refined modeling strategy was proposed in which only the local stiffness of the vehicle floor at the mounting points of the measurement device was incorporated into the MBD model. The remainder of the vehicle structure was modeled as rigid bodies to minimize modeling effort and computational cost. The FEM model was employed to represent contact behavior and elastic–plastic deformation of the force plate during road interference, and the MBD and FEM models were coupled to simultaneously reproduce vehicle motion and structural response.

The effectiveness of the proposed co-simulation method was validated through comparison with vehicle test results at multiple vehicle speeds. As shown in Fig.1, incorporating local floor stiffness markedly improved the agreement between simulated and measured stress responses. Time-history comparisons at 20 km/h and 30 km/h (Figs.2) demonstrate that the refined model accurately reproduces both stress gradients and peak stress values observed in the experiments. Furthermore, comparisons of contact locations between simulation and test results (Figs.3) confirm that the proposed method successfully captures the spatial characteristics of road interference events.

These results demonstrate that accurate prediction of underbody stress and contact location can be achieved by modeling only the critical local stiffness along the load transmission path, without requiring full flexible-body modeling of the entire vehicle structure. The proposed co-simulation method provides an efficient and reliable tool for underbody component design and is expected to contribute to improved reliability in future vehicle development.

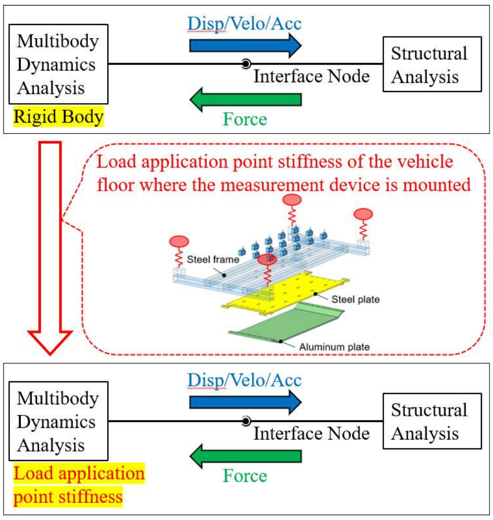


Fig.1 Accuracy improvement study

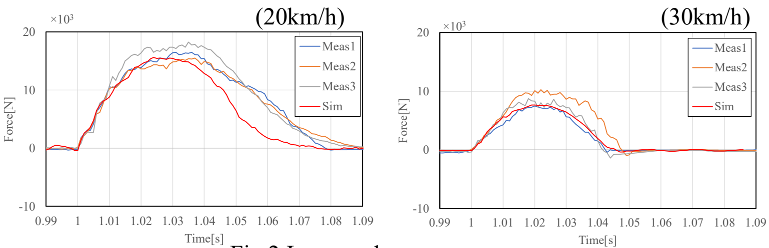
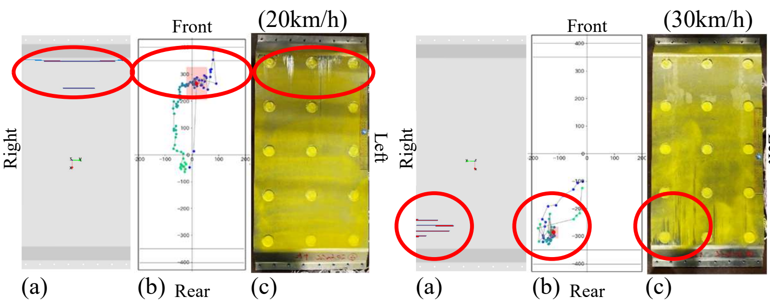


Fig.2 Improved stress time history



(a) Simulation result, (b) AI-based estimation from strain measurement, (c) Post-test device showing actual contact marks

Fig.3 Contact location comparison