

Analysis of Pedestrian Chest Injury Mechanisms in High-Hood SUV Impacts

-Change in Whole-Body Kinematics of THUMS Induced by Vehicle Reaction Forces-

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Pedestrian thoracic injury is an important issue in high-hood SUV impacts because the vehicle front sequentially interacts with the pelvis, thorax, shoulder region, and head. This study investigated the mechanisms of rib strain in a 40 km/h pedestrian impact simulation using the THUMS pedestrian M50 v4.1 model and a high-hood SUV model. A baseline vehicle condition was compared with a stiffer condition in which the reaction force characteristics of vehicle front-end regions were increased while maintaining the same vehicle outer geometry and THUMS model.

Whole-body kinematics, vehicle-human contact responses, and maximum principal strain of the ribs were evaluated. The sequence of whole-body events was similar in the two conditions: the pelvis, T8, and head reached their maximum intrusion in this order. The stiffer condition showed earlier intrusion timings. In both conditions, high rib strains occurred at Rib10 in the lower thorax and Rib3 in the upper thorax. Rib10 maximum principal strain occurred at 58 ms and increased from 2% in the baseline condition to 4% in the stiffer condition. Rib3 maximum principal strain occurred at 98 ms and increased from 4% to 4.8% (Fig. 1).

The mechanisms of strain increase differed between the lower and upper ribs. For Rib10, Rib10 and the hood contact point were closest to each other near the timing of the maximum strain, and the closest distance was almost the same between the two conditions. However, at 58 ms, the vehicle deformation was smaller and the THUMS deformation was larger in the stiffer condition (Fig. 2). This indicates that greater local deformation was concentrated in the lower thorax when vehicle deformation was suppressed by the increased reaction force. Therefore, the Rib10 strain increase was attributed to local deformation caused by direct contact with the hood.

In contrast, Rib3 strain was concentrated in the posterior region near the rib root and was associated with local deformation with a torsional component (Fig. 3). The shoulder-hood contact force increased earlier and reached a higher peak in the stiffer condition (Fig. 4). This earlier suppression of shoulder-side motion increased the relative displacement of T3 with respect to the scapula, leading to greater local deformation with a torsional component and increased tensile strain at the rib root.

These results indicate that increased vehicle reaction force affects both lower and upper rib strains, but through different mechanisms: localized bending deformation associated with direct hood contact in the lower thorax and local deformation with a torsional component induced by relative motion between the scapular side and thoracic spine in the upper thorax.

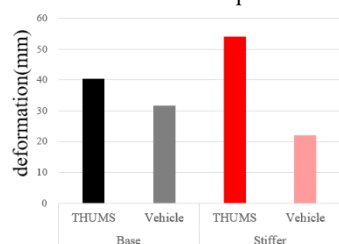


Fig.2 Deformation of the vehicle and THUMS at 58 ms

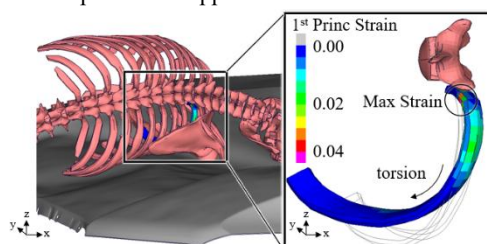


Fig.3 Strain contour of the Rib3 at 98 ms

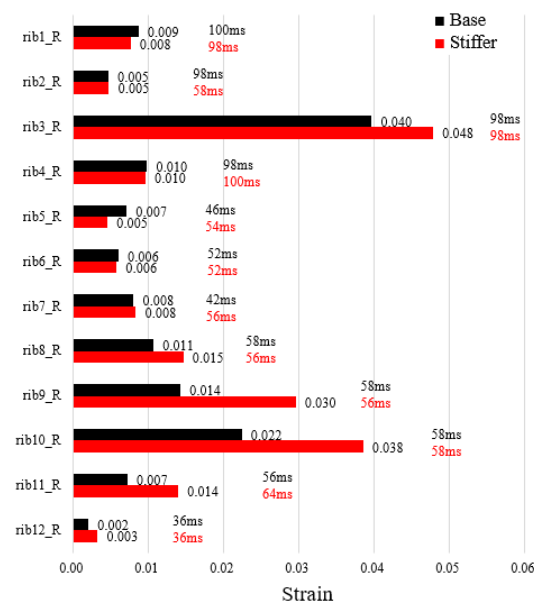


Fig.1 Maximum principal strain of each rib and the time at which it occurs

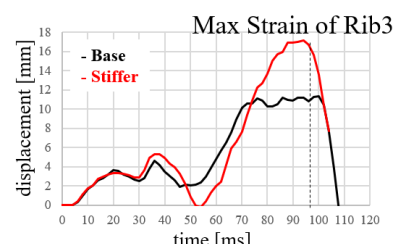


Fig.4 Relative Z-displacement of T3 with respect to the scapula