

Investigation toward Abdominal Injury Assessment Using Frontal Sled Simulations with a Human Body FE Model

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Abdominal injury is an important issue in reducing fatalities and serious injuries in frontal crashes; however, abdominal injury assessment using anthropomorphic test devices has not yet been established. This study analysed detailed Japanese crash data to define injury scenarios and examined abdominal organ responses through frontal sled simulations using THUMS AF05, a human body model representing a fifth percentile adult female.

The data included 28 AIS 2+ abdominal injuries among drivers involved in frontal crashes from 2013 to 2022. The seat belt was the most frequent injury source, accounting for 18 injuries, followed by the steering wheel rim with two injuries. Shoulder belt loading and steering wheel rim loading were assumed as upper abdominal injury scenarios. Because the seat belt was the injury source for all lower abdominal injuries and some injuries occurred at relatively low speeds, direct lap belt loading following submarining was assumed as the lower abdominal injury scenario.

THUMS AF05 Occupant Version 7.1 was positioned in a right hand drive sled model based on an NHTSA finite element model of a 2013 Honda Accord, as shown in Fig. 1. Five simulation conditions were defined based on the crash data analysis, as shown in Table 1. Conditions 1 and 4 were baseline conditions without additional abdominal loading factors. In Condition 2, the shoulder belt load limiter setting was increased. In Condition 3, airbag bottoming out was induced to reproduce loading of the thorax and upper abdomen by the steering wheel rim. In Condition 5, submarining was induced by eliminating knee restraint and raising the lap belt routing. The liver and spleen were evaluated using MPS95, defined as the 95th percentile maximum principal strain, while the small intestine was evaluated using the 95th percentile pressure.

In Condition 2, MPS95 of the liver increased from 0.581 in Condition 1 to 0.589. In Condition 3, MPS95 of the liver was 0.582, comparable to that in Condition 1, whereas MPS95 of the spleen increased from 0.365 in Condition 1 to 0.422 in Condition 3. These responses corresponded to the loading scenarios assumed from the crash data. However, the changes in MPS95 of the liver from Condition 1 to Conditions 2 and 3 were small. As shown in Fig. 2, excessive liver strain developed near attachments to surrounding tissues during forward motion of the liver. This response may have influenced MPS95, indicating that the biofidelity of the organ responses predicted by THUMS AF05 requires further investigation. In Condition 5, the lap belt slipped off the pelvis, moved upward, and directly loaded the small intestine. The 95th percentile pressure of the small intestine increased from 0.299 MPa in Condition 4 to 0.354 MPa in Condition 5, showing that lap belt intrusion affected the response of the small intestine. Overall, the simulations produced organ responses corresponding to the assumed injury scenarios, indicating the potential use of HBMs in abdominal injury assessment. Future work should examine other HBMs and relate organ responses obtained from HBMs to measurements from anthropomorphic test devices.

Table1 Simulation matrix (“↑” indicates the baseline setting)

	Sled pulse	Lap belt routing	Knee-to-instrument-panel contact	LL setting	Airbag venting characteristics
Cond. 1: Baseline	50 km/h FWRB	Standard	Yes	3 kN*	Baseline
Cond. 2: Increased LL	↑	↑	↑	2× baseline	↑
Cond. 3: Airbag bottoming-out	↑	↑	↑	0.1× baseline	2× baseline
	Sled pulse	Lap belt routing	Knee-to-instrument-panel contact	LL setting	Airbag venting characteristics
Cond. 4: Baseline	35 km/h FWDB	Standard	Yes	3 kN*	Baseline
Cond. 5: Submarining	↑	59 mm upward at the midsagittal plane	No	↑	↑

* Shoulder belt load at the shoulder

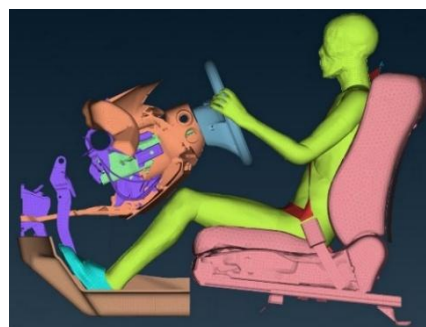


Fig.1 THUMS AF05 positioned in the sled model

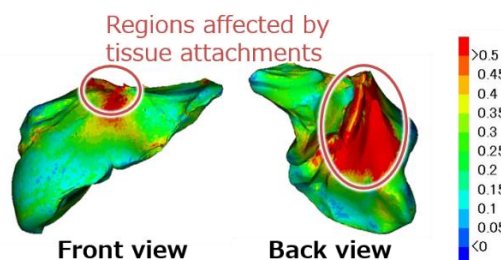


Fig.2 Contour map of liver maximum principal strain in Cond. 1 at 60 ms