# Comparison of Chest Responses between THOR 50th Percentile Dummy and THUMS AM50 Version 4 in Frontal Oblique Impact with Inflatable Seatbelt

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## I. INTRODUCTION

One common type of serious injury in frontal collisions is injury to the chest, especially for elderly car occupants [1]. Advanced load distributing restraint systems, like inflatable seatbelts, could reduce the risk of thoracic injury and thus increase the protection of car occupants, especially elderly. Previous studies reported a more distributed loading on the chest with inflatable seatbelts compared to conventional three-point seatbelts. It was recognised that load distribution helps to decrease chest deflections [2-5]. Those studies assumed pure frontal impacts. The effectiveness of inflatable seatbelts in frontal oblique impact is not understood. The occupant moves diagonally in frontal oblique impact. The seatbelt position relative to the occupant chest could change during the impact. In laboratory tests with dummies, this affects chest deflection measurements. The objective of this study was to examine the effectiveness of inflatable seatbelt systems in a frontal oblique impact and to analyse the influence of oblique motion of the occupant on chest injury risk by comparing chest responses between THOR 50th percentile and THUMS AM50.

## II. METHODS

Simulations were conducted using finite element (FE) models of THOR 50th percentile dummy (LS-Dyna Version 1.6.1) and THUMS Version 4.02 AM50, as shown in Fig. 1. For both models, comparable seating postures in a semi-rigid seat [6] were assumed. For this study, conventional and inflatable three-point seatbelt systems were used [5]. Both systems had a retractor with a 4 kN load limiter and the pre-tensioner was not activated. The pressure in the inflatable seatbelt (ΔP) was 32 kPa constant. The sled model of the THOR dummy was previously validated to a series of pure frontal impact sled tests using both seatbelt systems. The sled deceleration represented a frontal impact at 45 kph [7] (Fig. 2). The impact directions were assumed to be 30 deg (frontal oblique) and 0 deg (pure frontal). Table I summarises the simulation matrix. For chest injury assessment, the maximum chest deflections were obtained from the four IR-TRACC measurements in the THOR dummy, while the maximum principal strains in the ribs were calculated for THUMS.

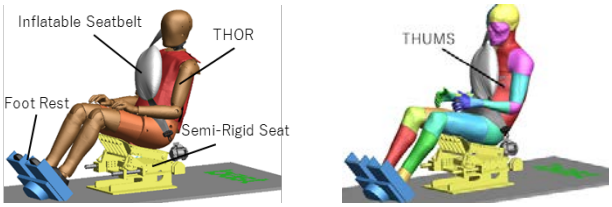


Fig. 1. Simulation models.

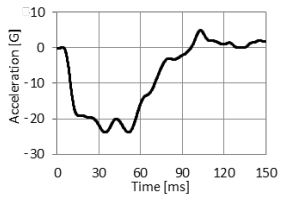


Fig. 2. Sled deceleration.

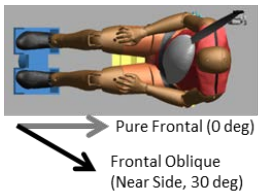


Fig. 3. Impact direction.

TABLE I
SIMULATION MATRIX

| Case | Collision | Occupant | Seatbelt |
|---|---|---|---|
| 1 | Frontal Oblique (Near Side, 30 deg) | THOR 50th | Conventional |
| 2 | | | Inflatable |
| 3 | | THUMS AM50 | Conventional |
| 4 | | | Inflatable |
| 5 | Pure Frontal (0 deg) | THOR 50th | Conventional |
| 6 | | | Inflatable |
| 7 | | THUMS AM50 | Conventional |
| 8 | | | Inflatable |

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## III. INITIAL FINDINGS

Figure 4 shows the chest injury assessment values. For the THOR dummy, the inflatable seatbelt reduced the chest deflections by 6 mm for the frontal oblique impact and by 19 mm for the pure frontal impact. In the case of THUMS, the maximum principal strain in the ribs was 1.6% lower with inflatable seatbelt than those with the conventional seatbelt in the frontal oblique impact. The reduction was 1.8% in the pure frontal impact. Figure 5 shows the pressure distributions on the chest (under the seatbelt) at 70 ms in the frontal oblique impact. The dotted lines indicate the initial path of the conventional seatbelt. The four circles on the THOR chest indicate the initial position of the four measurement points. The conventional seatbelt moved towards the neck during impact in both THOR and THUMS. Thus, none of the four measurement points was directly loaded by the conventional seatbelt in THOR. The inflatable seatbelt distributed the load over a wide area of the chest in both THOR and THUMS. Thereby, three of the four IR-TRACCs were directly loaded. The maximum principal strain in the ribs was identified regardless of the loading area in THUMS.

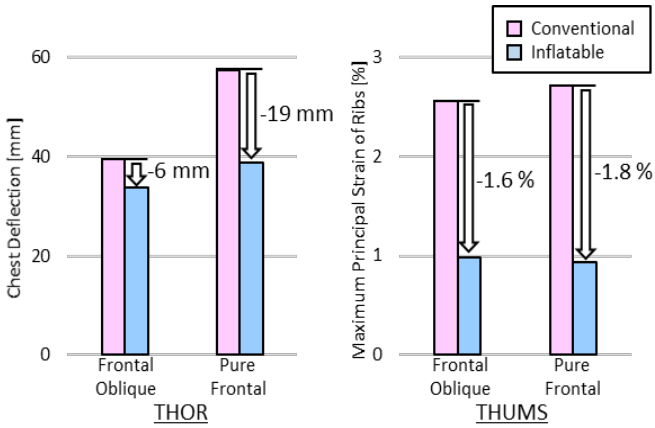


Fig. 4. Chest injury assessment values.

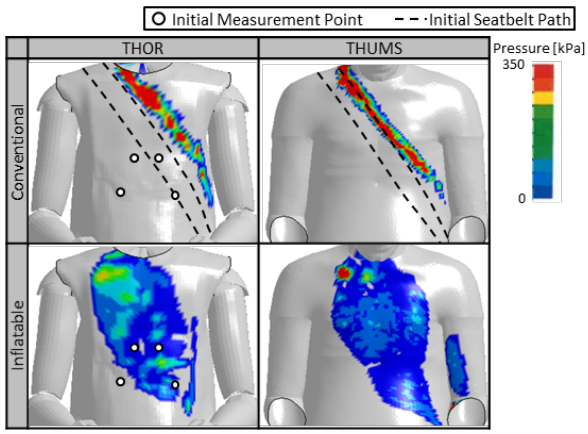


Fig. 5. Pressure distributions on chest (at 70 ms, frontal oblique impact).

## IV. DISCUSSION

The simulation results in the pure frontal impact were consistent with those reported in previous studies [2-5]. The chest injury assessment values with the inflatable seatbelt were lower than those with the conventional seatbelt in both THOR and THUMS. The same trend was observed in the frontal oblique impact. These results confirmed that the inflatable seatbelt distributed the load over a wide range of the chest. The reduction of the maximum principal strain of the ribs by the inflatable seatbelt in THUMS was similar between the frontal oblique impact and the pure frontal impact. On the other hand, the reduction of chest deflection in THOR by the inflatable seatbelt in the frontal oblique impact was much smaller than that in the pure frontal impact. It is considered that the chest deflection generated by the conventional seatbelt was small in THOR because the seatbelt moved towards the neck in the frontal oblique impact, as shown in Fig. 5. Further research is needed to adequately measure the chest deflection in THOR, especially in frontal oblique impact. This study focused on the near-side frontal oblique impact. The chest response during the far-side frontal oblique impact will need to be investigated in the future.

## V. REFERENCES

[1] Wisch, M., *et al.*, IRCOBI, 2017.
[2] Kent, R., *et al.*, *Stapp Car Crash J*, 2011.
[3] Sundararajan, S., *et al.*, *Stapp Car Crash J*, 2011.
[4] Jin, X., *et al.*, IRCOBI, 2019.
[5] Kitagawa, Y., *et al.*, IRCOBI, 2013.
[6] Uriot, J., *et al.*, *Accid Anal Prev*, 2015.
[7] Eggers, A., *et al.*, ESV, 2017.