Influence of Occupant Arm Position on Thoracic Response in Side Impact

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Motivation

- Thoracic injuries resulting from side impact collisions continue to be a leading cause of fatality and severe injury.
- 30% of 12,679 fatalities in passenger car collisions were attributed to side impact in 2011 [Fig. 1] (IIHS, 2012).

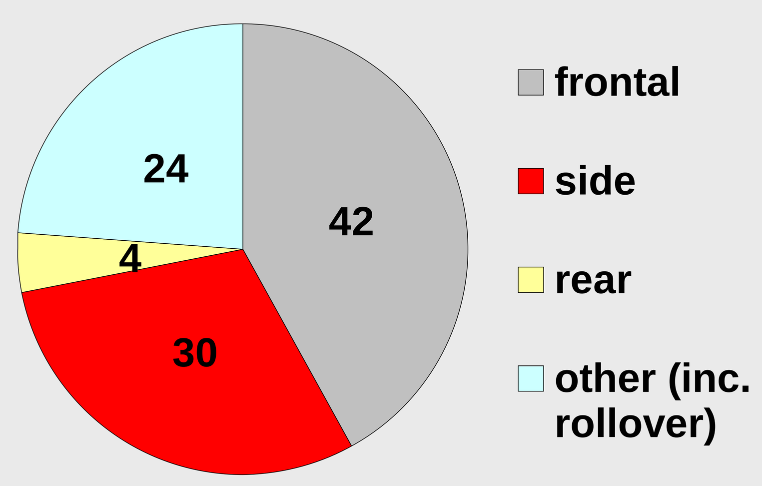

Figure 1: Distribution of fatalities in passenger cars in 2011 (IIHS)

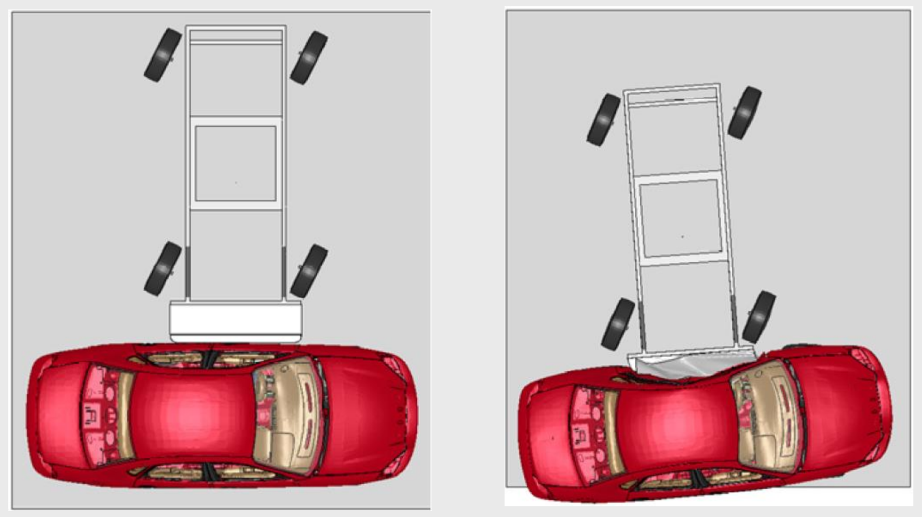

Figure 2: Test configuration: side impact at 61 kph

- Side impact scenarios are challenging to address due the limited crush zone.
- Restraints and protective systems are evaluated with ATDs in a specified typical driving position.
- Occupant location in the car can have a significant influence on predicted injury outcome (Watson et al. 2011).
- The current study compared ATD and human body model response considering varying arm positions.

ATD and Human Body models

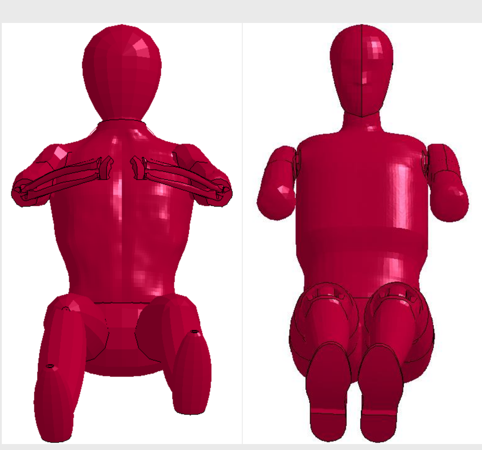

Figure 3: Human body model [Left] and the ATD model [Right]

- The human body model was validated for pendulum and side sled impact tests (Forbes 2005; Campbell 2009; Yuen 2009).
- ES-2re finite element model (Dynamore, Version 4.1) calibration tests verified following the United States Federal Code.

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Methods

- ES2re ATD and human thorax FE model were integrated into a mid-size sedan FE model (2001 Ford Taurus, NCAC) including a pre-crash simulation to account for static seat deformation.
- NCAP 61 km/h moving deformable barrier side impact test [Fig. 2].
- Three arm positions considered: vertical, driving (20 degrees down from horizontal) and horizontal [Fig. 4].
- Response assessed using maximum rib deflection and Viscous Criterion (NHTSA, ECE 95).

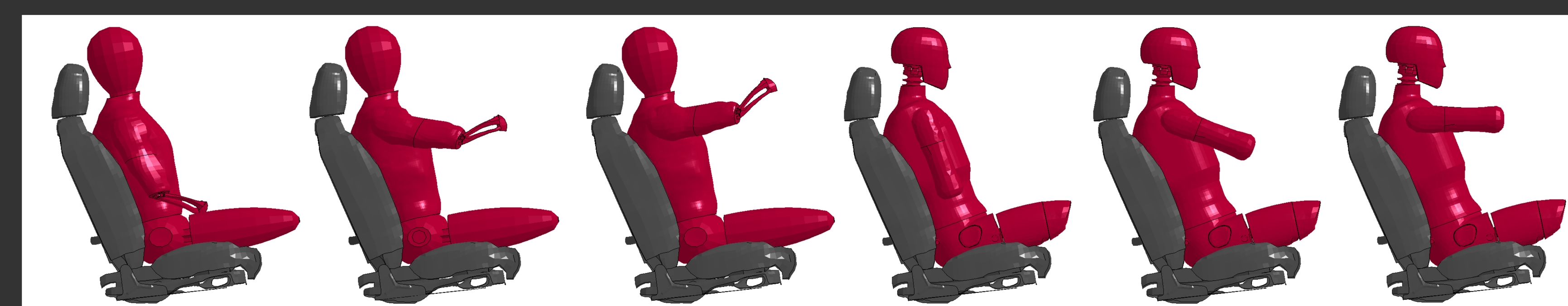

Figure 4: Arm position for Human [Left] and ES2re [Right] models.

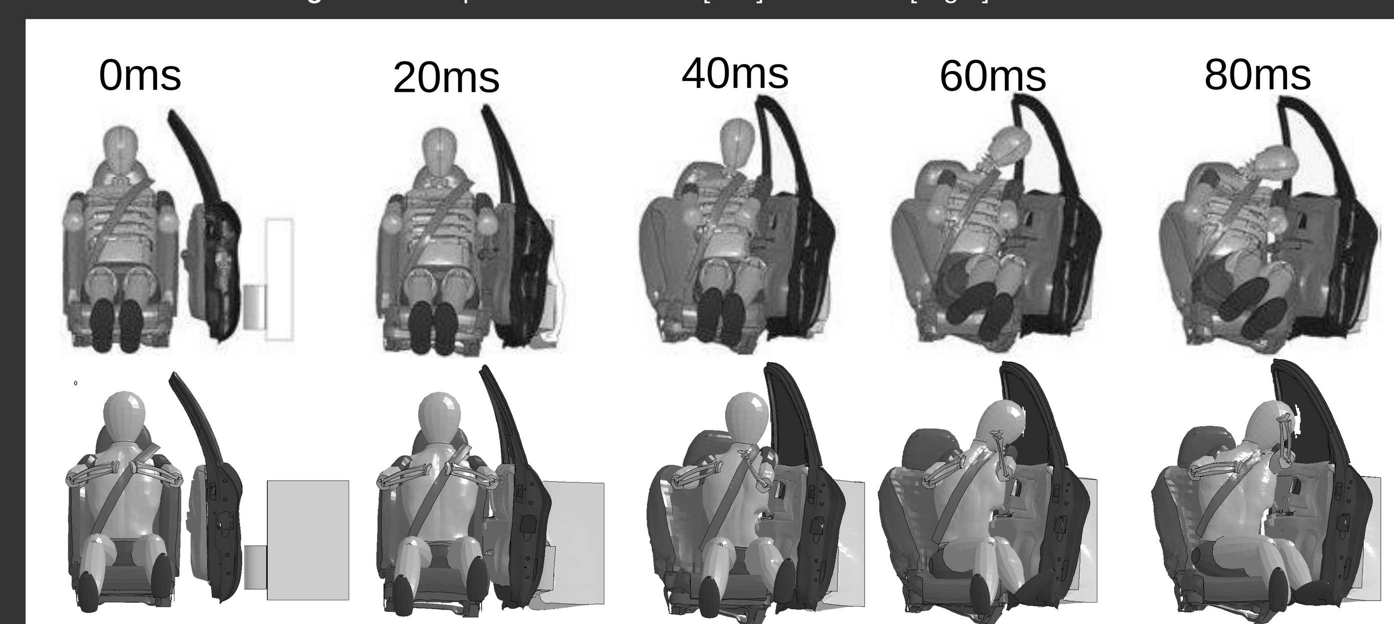

Figure 5: Comparison of the ATD [Upper row] and Human [Lower row] models kinematics for the driving position.

Vehicle model validation

Figure 6: Deformation after the impact .

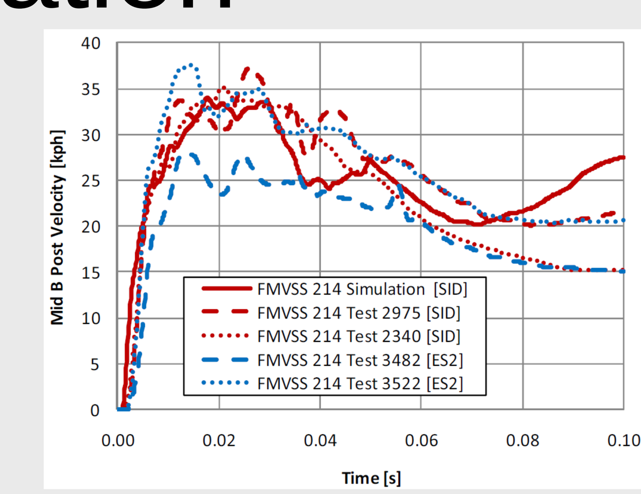

Figure 7: Part of the validation data: B pillar velocity .

- The Ford Taurus 2001 model was validated by Watson et al. (2010, 2011) using NHTSA side impact data.
- The MDB model was verified by simulating impacts into a flat rigid wall and a 300 mm diameter rigid pole.

Results

- The largest rib deflection was a maximum for the human model in the vertical position (Fig. 8). VC_{Max} trends were similar.
- The ES-2re maximum rib deflection was consistent for all arm positions (Fig. 8). VC_{Max} was lower for the vertical arm position.
- Regulatory injury criteria limits were exceeded at USNCAP speed of 61 kph but not in subsequent simulations at lower FMVSS 214 speed of 54 kph (results not shown here).

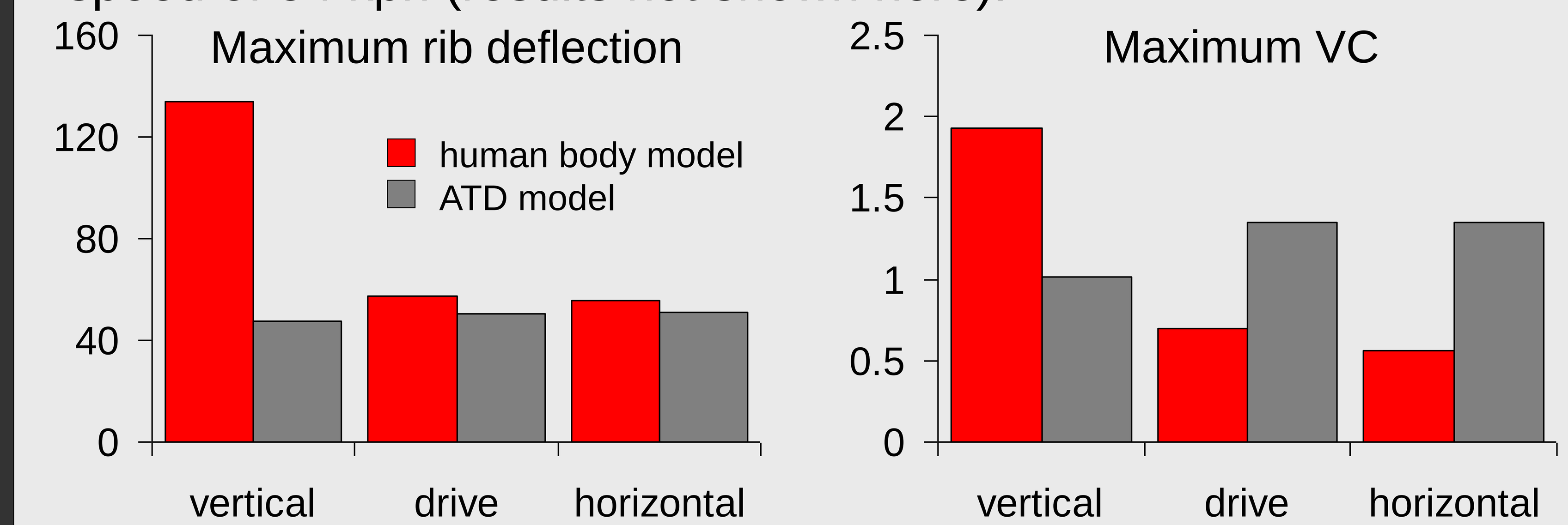

Figure 8: Predicted response for changing arm position, 61 kph NCAP impact

Discussion and Conclusions

- Increased impact velocity (61 kph versus 54 kph) resulted in an increase in response (deflection and VC_{Max}).
- The human thorax model was sensitive to arm position. This sensitivity was attributed to:
  - Direct load transfer to the thorax through the vertical arm.
  - Movement of the arm and shoulder anterior to the thorax (driving and horizontal positions), reducing load transfer to the thorax.
- The primary differences between the human and ATD models were the shoulder kinematics and arm compliance.
- The ATD model was not sensitive to arm position although the human model did demonstrated potentially significant effects.

Limitations

- Additional impact scenarios and the effect of occupant position (fore/aft) coupled with arm position should be considered.
- The vehicle considered in this study was originally tested at 61 kph with the USSID ATD, validation with ES2re was carried out at 54 kph.

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