Investigation of Human Body Model Response to Different Lateral Loading Conditions

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I. INTRODUCTION

Injuries to the thorax are one of the leading causes of fatalities in side impact crash scenarios [1]. Although new safety systems, such as the introduction of thorax airbags and side curtain airbags have resulted in a reduction of fatalities, the reduction has been smaller than expected [2]. Due to the high cost and complexity of full vehicle testing, simplified tests (e.g. pendulum impact, sled) have been used to investigate side impact response; however, it is hypothesized that the differences between the laboratory tests using Anthropometric Test Devices (ATDs) and Post-Mortem Human Subjects (PMHSs), and injury reported in field data are due to the effect of different side impact loading conditions.

Advanced Human Body Models (HBMs) are designed and validated for omni-directional impacts, and capable of predicting injuries at the tissue level, enabling parametric studies on the effect of posture, position in the vehicle, interior contact, and restraints on predicted occupant response in side impact. Since the arm is the primary load transmission path in side impact, it is important to understand the effect of pre-crash occupant arm position on thoracic response [3]. Different authors have investigated the effect of arm position in PMHS tests under different loading conditions, with differing results [4-6].

The aim of this investigation was to use a finite element HBM to evaluate and compare side impact response for different lateral impact conditions including the vehicle environment.

II. METHODS

A HBM with detailed thoracic section [7-10] was subjected to lateral impact scenarios including pendulum, rigid sled, and a full vehicle moving deformable barrier (MDB) impact [11] (Table 1). Simulations were performed using a commercial explicit finite element code (LS-Dyna, LSTC).

TABLE I
SUMMARY OF THE LATERAL IMPACT CONDITIONS

Impact type	**Free-flight**			**Velocity-pulse**	
Impactor type	Pendulum (Figure 1: AF/BF)	Rigid sled (Figure 1: CF/DF)		Pendulum (Figure 1: AV/BV)	Full vehicle MDB (Figure 1: EV)
Impactor weight / dimensions	23.4kg, ϕ152mm	NHTSA	WSU	23.4kg, ϕ152 mm	Vehicle door
Initial velocity	4.3 m/s	6.7 m/s		5.6 m/s, 51mm displacement	17 m/s (NCAP)

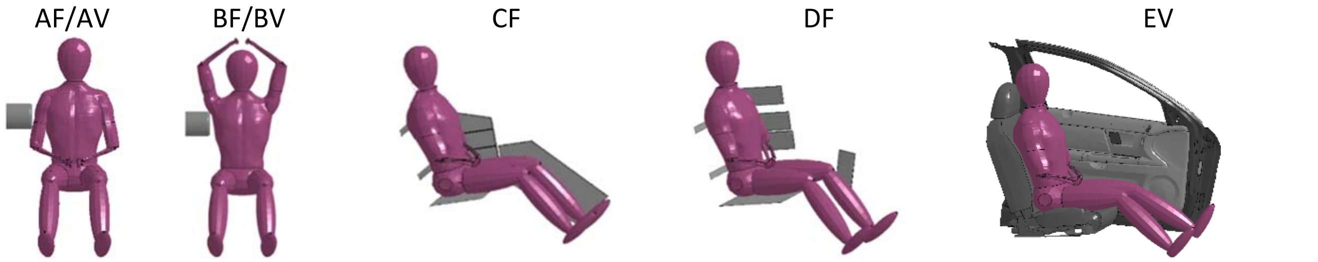

Fig. 1: Lateral impact scenarios considered in this study: AF, BF) free-flight pendulum [12]; AV/BV) velocity-pulse pendulum [13]; CF) NHTSA free-flight rigid sled [14]; DF) free-flight, WSU rigid sled [15]; EV) NCAP full vehicle (vehicle model not shown for clarity) [16].

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The investigated scenarios were classified as concentrated load (pendulum, Figure 1 AF/BF and AV/BV), distributed load (Figure 1 CF and DF), and a full vehicle case (Figure 1 EV). The impact type was defined as free-flight (pre-defined initial velocity, denoted by a ‘F’ in the load case identifier), and velocity pulse (controlled velocity pulse, limited displacement, denoted by a ‘V’ in the load case identifier). The initial velocity of the rigid sled was adjusted to match the kinetic energy transferred to the occupant body comparable to the NCAP full vehicle MDB scenario. Two arm positions were considered: arms above head and arms parallel to the torso. Model response was assessed based on chest deflection and maximum Viscous Criterion (VCmax) measured at three chest band levels.

III. INITIAL FINDINGS

The investigated injury metrics were sensitive to occupant arm position, and the sensitivity differed between the free-flight and velocity-pulse impacts. Chest deflection and VCmax demonstrated comparable sensitivity to free-flight impacts (56-76% increase of both chest deflection and VCmax for load cases CF and DF, Figure 2). For velocity-pulse impacts (load cases AV/BV, and EV), VCmax was observed to be 3-7 times more sensitive than chest deflection to arm position, due to the shorter time between maximum compression and maximum velocity. Injury metrics decreased for the concentrated load velocity-pulse impact (load case AV), when the occupant arm was in the loading path (-5% for the chest deflection, -36% for the VCmax, Figure 2) compared to when the arm was raised (case BV). However, when the arm was in the loading path the injury metrics increased for velocity-pulse load case EV and did not change significantly for free-flight pendulum impacts.

a) b)

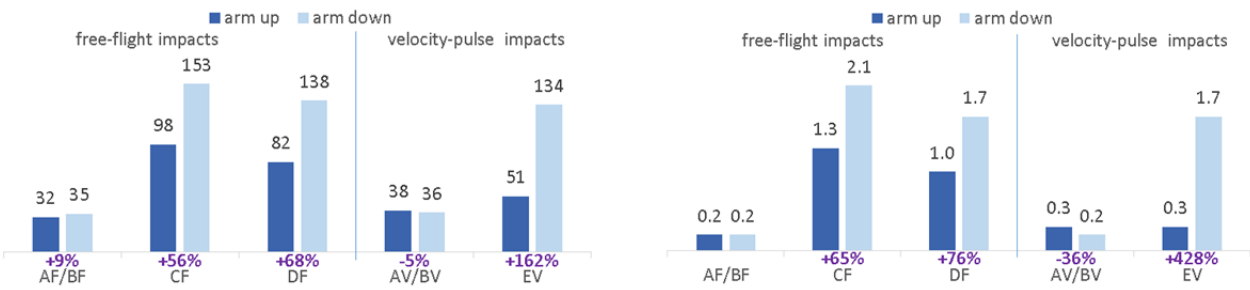

Fig. 2: Maximum a) chest deflection and b) VCmax for free-flight and velocity-pulse impacts.

IV. DISCUSSION

The HBM offered repeatable test conditions and the ability to vary single parameters to investigate side impact response. When the arm was in the loading path, the response sensitivity depended on the on impact type. The HBM prediction confirmed previous findings regarding the protective effect of the arm for a low-speed velocity pulse pendulum impact [7]. In contrast, for the full vehicle impact the arm acted as a load transmission path leading to higher values of chest deflection and VCmax. For the impact types with a comparable amount of energy transferred to the HBM (NHTSA sled and NCAP full vehicle with MDB), the chest deflection patterns with arms in the loading path were similar. The WSU sled test resulted in lower response compared to the NHTSA sled test due to engagement of the shoulder. It was found that vehicle side impact conditions were similar to an applied velocity-pulse and demonstrated a different sensitivity to arm position, depending on type of loading (i.e. arm in the loading path increased injury metrics for a distributed load, and decreased the injury metrics for concentrated load). This is an important consideration in evaluating side impact response. Future research will include investigating the effect of thorax airbags on side impact loading.

V. REFERENCES

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