Simulate Uniform Restraint Concept for Wide-Ranging Crash Protection

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I. INTRODUCTION

Seatbelts and airbags have been proved to be effective restraint devices for vehicle occupant impact protection. However, a seatbelt provides concentrated force on the occupant chest, which may be disadvantageous to elderly occupants. Airbags can spread the force on the occupants, but it could also generate disproportional risks to small or out-of-position occupants. A uniform restraint concept is proposed in this study. The concept lies in providing spread and constant restraint forces on the knees, thorax, shoulders and head, respectively. Those are relatively sturdy parts of the human body [1]. This study builds on previous work by exploring how the uniform restraint concept controls occupant posture during impact and how it works in different impact severities.

II. METHODS

A finite element human body model (HBM) in a seated driving position (Academic THUMS Version 4.0.1 for LS-DYNA) was used in this study. As shown in Fig. 1 (a), the HBM was restrained by "plates" against the knees, chest, shoulders and head, which can spread the restraint forces and control occupant posture. The chest plate was deformable to reduce "hard" contact areas when interacting with the upper torso, and the other three plates were rigid. The chest plate and the shoulder plate were connected to form a single piece, like a vest. The restraint plates were against the respective body parts. The head plate and the knee plate were only allowed to move in the X direction, while the shoulder plate and the chest plate had all the degrees of freedom. As the head and the knees moved forward during the crash, the head plate and the knee plate were pushed forward and meanwhile provided constant restraint forces to the respective body parts. The upper edge of the shoulder plate was restrained by two straps (marked as upper force) and the lower edge of the chest plate was restrained by two other straps (marked as lower force). During a crash, the moving direction of the chest plate and the shoulder plate can change to accommodate the posture of the torso as the upper torso moves and rotates forward, and the four straps can provide constant restraint forces as the shoulder plate and the chest plate are pushed by the moving occupant. Two crash severities with initial impact velocities of 48km/h and 81km/h, respectively, were simulated. The crash pulse of 48km/h (baseline) is from a sled test, and that of 81km/h pulse was scaled from the baseline velocity (Fig. 1 (b)).

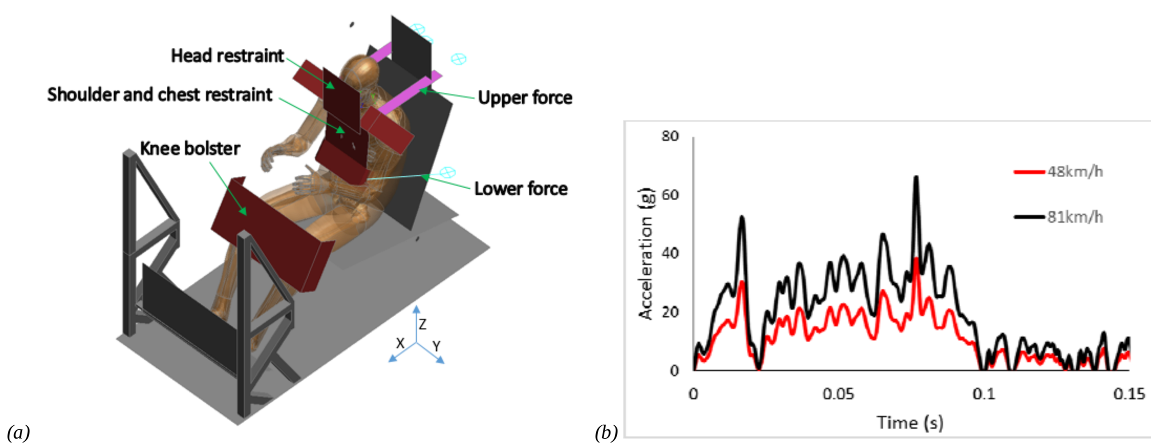

Fig. 1. (a) Model set-up; (b) Crash pulses of impact

The restraint force levels (Table 1) provided by the plates were chosen through manual optimisation. In

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Case_48, the restraint forces were chosen for inducing a slightly leaning forward posture, and in Case_81, they were chosen for balancing chest excursion and chest acceleration. Head acceleration at the CG location and chest acceleration at T8 were monitored. Chest deflection was monitored and obtained in the same way as that in [2]. Rib fracture is not defined in the model, but plastic strain in ribcage was monitored to assess rib fracture risk.

TABLE I

RESTRAINT FORCES OF UNIFORM RESTRAINT AND RESULTS OF BODY PART EXCURSIONS AND INJURY PARAMETERS

	Restraint force (kN)				*Excursion (mm)			Acceleration (g)		HIC	***Chest deflection (mm)
	Head	Upper force	Lower force	Knee	Head	Chest	Knee	Head	**Chest		
Case_48	0.6	1.6×2	2.4×2	4.0	404	244	243	40.2	39.5	210	6.7
Case_81	1.0	1.8×2	1.8×2	8.5	770	670	259	48.8	45.4	302	16.6

*Represented by nodes X motion relative to the duck in global coordinate

**Measured at T8

***Represented by sternum X motion relative to the T8 local coordinate

III. INITIAL FINDINGS

The simulation results (Table 1) show that the uniform restraint can provide good protection. The occupant motion, especially that of the upper body, can be well controlled by the restraint forces applied to the body parts through the restraint plates. Owing to the spread restraint force, the "vest" on the chest and the shoulders are more effective in rib fracture prevention than a seatbelt system. In [3], sled tests with PMHSs (post-mortem human subjects) restrained by seatbelt were carried out, showing that the PMHSs sustained at least 16 rib fractures in 40km/h frontal impacts. The plastic strain levels in the ribs monitored in this study indicate that rib fractures are unlikely to occur under 48km/h impact, and that only few rib fractures (should be no more than two) might occur in the 81km/h case. The uniform restraint system is able to provide protection in high-speed crashes of 81km/h. In the high-speed case, the occupant posture is well controlled by the restraint forces applied to the individual body parts (Fig. 2 (a)), the injury readings are acceptable, and the energy absorbing spaces needed by the lower body and the upper body are reasonable compared to the occupant space shown in [4] (Fig. 2 (b)).

(a) (b)

Fig. 2. (a) Occupant posture at moment of largest chest excursion (81km/h); (b) Typical occupant space [4]

IV. DISCUSSION

In the situation of seatbelt restraints, seatbelt penetration to ribcage usually results in large chest deflection and concentrated deformation in sternum and ribs. In contrast, the chest plate and the shoulder plate in the uniform restraint can provide energy absorbing cushioning to the ribcage spread in such a way that the rib strain and chest deflection are significantly reduced. Another merit of the uniform restraint is that it can control body posture well during a crash, and it appears that the knee bolster plays a significant role in posture control.

These results are part of a preliminary study focused on assessing the effectiveness of the uniform restraint concept. The system may work better if the restraint forces are fully optimized. By making the restraint forces changeable, the system can be adaptive to different crash severities and occupant body sizes. The uniform restraint system is only a proposed concept in this preliminary study, and at this stage we do not address how such restraint forces would be achieved in reality.

V. References

[1] Adomeit D., SAE Paper, 1977.
[2] Shaw G, et al., Stapp Car Crash Journal, 2009.
[3] Sundararajan, et al., Stapp Car Crash Journal, 2011.
[4] Michaelson J, et al., Stapp Car Crash Journal, 2008.