A study on injury and kinematics of rear seat child occupant in side impact

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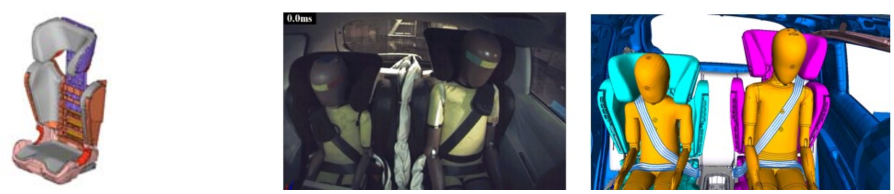
I. INTRODUCTION

Vehicle consumer information programs are beginning to provide ratings of rear seat occupant protection, including large child and/or small adult female performance. Large child occupants- the Q6 six year old and Q10 ten year old dummies were developed in the EPOCH(Enabling Protection for Older Children) as new child dummies which have shown improved bio-fidelity than the P-dummy series [1]. Large child occupants will be evaluated the ENCAP (Euro New Car Assessment Programs) [2] beginning in 2016 and KNCAP (Korean New Car Assessment Programs) beginning 2017. The objective of this paper is to evaluate the injury assessment values and kinematics of large child dummies in side impact. A vehicle crash test was conducted with the Q6 and Q10 dummy in 55km/h side impact with AE-MDB (Advanced European Mobile Deformable Barrier) for simulation correlation. The Q10 is positioned in a high-back booster (HB) on the struck-side of the vehicle and the Q6 is positioned in a high-back booster on the far-side. The baseline restraint system consisted of a 3-point ELR (Emergency Locking Retractor) seatbelt and RRAB (Roof Rail Airbag).

II. METHOD

FE modeling of a high back booster seat was conducted by using 3D laser scan data. Based on the scanned surface data of the booster seat, FE mesh was constructed using a Hyper-mesh pre-processor. A series sled test simulations were performed to validate the FE modeling of the booster seat with respect to the mass, FE contacts, deformation and overall model behavior of booster seat. Rotation of booster seat back and height of headrest can be adjusted. The validated booster seat model developed from these sled test simulations was used for this study. A correlation was developed between full vehicle LS-DYNA simulation and physical sled test with dummy kinematics and injury responses. Five case studies as shown in Table 1 were performed to evaluate shoulder belt load limiters, retractor pretensioners, roof rail airbag, and high back and backless booster seats.



(A) CRS Modeling (B) Full scale vehicle modeling

Fig. 1. FE Modeling

TABLE 1 Test matrix

Dummy	Q10					Q6		
Restrains Systems	CRS	L.L	RRAB*	RSIA	2nd row Head restraints	CRS	L.L	Remark
Base case	HB	ELR only	✓			HB	ELR only	
Case 1	HB	4kN CLL** include retractor pretensioner	✓			HB	4kN CLL include retractor pretensioner	
Case 2	HB		✓	✓		HB		with DLT***
Case 3	BL		✓	✓		HB		weighted
Case 4	BL		✓			N/A	N/A	N/A
Case 5	BL		✓	✓	✓	N/A	N/A	N/A

*RSIA(Rear Side Airbag), **CLL(Constant Load Limiter), ***DLT(Dynamic Locking Tongue)

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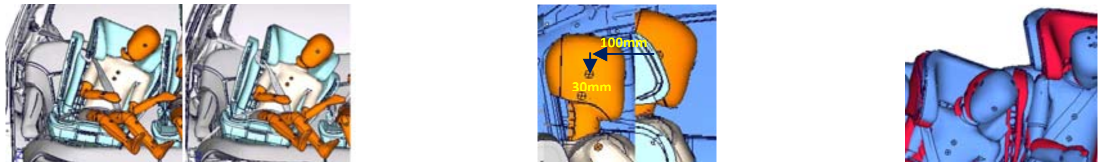
III. INITIAL FINDINGS

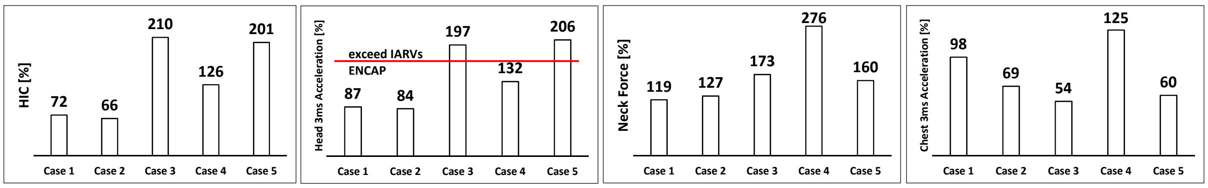


(A) Comparison of dummy kinematics of Q6 in booster (Left: Base / right: Case 3)

(B) Comparison of initial set up position with and without backrest on booster of Q10 (Left: BL / right: HB)

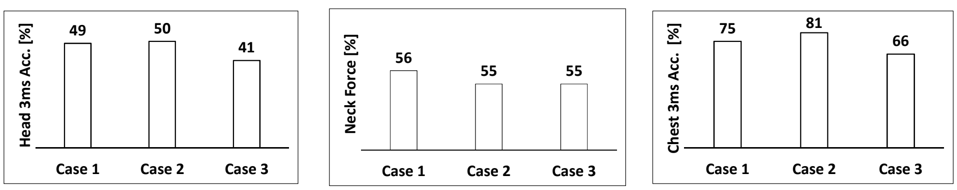
(C) the retractor pretensioner effect with RPT shown in red (Base), without RPT shown on blue (Case1)

Fig. 2. Comparison of dummy kinematics



(A) HIC15 (B) Head 3ms acceleration (C) neck force (D) chest 3ms acceleration

**Fig.3 Q10 injury value plots



(A) Head 3ms acceleration (B) neck Force (C) chest 3ms acceleration

**Fig.4 Q6 injury value plots

** Normalized [%] with respect to the values of Base case.

For Q10 case study results - Head, neck and chest injury values were analyzed and injury values with HB booster (Case1, 2) shows better result than BL booster (Case3, 4, 5) as below.

Head HIC15 value is reduced 66% in case 2 with RRAB & RSIAB, and 72 % in case 1 with RRAB compared to the base case (vehicle crash test result). For Case 3, 4, 5 using BL booster, HIC15 value increase 126 % in case 4 with RRAB, 201 % in Case 5 with RRAB & RSIAB & 2nd row head restraint system and 210 % in Case 3 with RRAB & RSIAB (Fig.3 (A)). Head 3msec acceleration exceeded IARVs of ENCAP in Case 3 and Case 4, due to a lack of interaction with the RRAB (Fig.3. (B)). This was a result of the C.G of head being located more rearward with the BL booster than with the HB booster (Fig.2. (B)). As case 2, 3, 5 results demonstrate, a side airbag can reduce chest acceleration by 54-69% (Fig.3. (D)).

For Q6 case study results - In the base case of HB booster for Q10, contact occurred between the Q6 and Q10 because three point belt (ELR only) did not constrain the dummy behavior in lateral direction as shown in Fig.2 (A). The combination of load limiter and retractor pretensioner were effective to secure space between the Q6 and Q10 to avoid direct contact between dummies. Fig.2 (C) shows the differences between ELR only and CLL with retractor pretensioner seat belt. The CRS and occupant excursion with ELR only is shown in blue color while the pre-tensioner effect is shown in red color at 80 msec. The DLT demonstrated a small improvement in the head and chest acceleration for Q6 (Case 2) when used with a CLL and retractor pretensioner.

IV. DISCUSSION

In this paper, five case studies are performed based on correlation of a full vehicle LS-DYNA model and to evaluate side impact restraint systems for child occupant protection in a 55kph AE-MDB side impact test mode. The HIC15 of the Q10 is reduced up to 66% due to the use of high back booster. (Case 2). The chest acceleration of the Q10 is reduced due to the use of rear side airbag. (Case 2, 3, 5). This study shows that the HB booster is more effective than BL booster to protect the Q10 dummy on the struck side of the vehicle. Also, the combination of load limiter and retractor pretensioner are effective to secure space between the Q6 and Q10 to avoid direct contact between dummies.

V. References

[1] Waagmeester K, Burleigh M, European Commission, EPOCh Project, Work Package 1, Task 1.2, Deliverable D1.2, Internet: http://www.epochfp7.org/Publications.aspx, 2009

[2] Euro NCAP Assessment protocol, Child Occupant Protection, V7.0.1., Internet: http://euroncap.blob.core.windows.net/media/21508/euro-ncap-assessment-protocol-cop-v701.pdf, 2016