REDUCING NECK INJURIES BY CONTROLLING SEAT BACK DYNAMIC MOVEMENT

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ABSTRACT

Neck injuries caused by rear-end collision are the most common injury type in motor vehicle accidents. The exact mechanism that causes whiplash is still not agreed upon. What has been agreed upon is that reducing relative movement between head and torso reduces neck injury. There are two ways to reduce relative movement between head and torso. One is supporting the passenger's head as fast as possible. Head acceleration is increased, reducing the relative acceleration between head and torso. This approach is the most common way to prevent whiplash injuries. The other way is to reduce torso acceleration by controlling the seat back and reducing the relative acceleration between head and torso. Based on benchmark test results, the second approach is an easy and robust way to handle the newly enhanced KNCAP test protocol. This study addresses a neck injury protection device to deal with enhanced neck injury rating systems in KNCAP & EURONCAP by controlling seat back frame movement. The device has been built, simulated, and tested.

INTRODUCTION

The perception that frontal and side collision has a direct relationship to passenger safety in a vehicle collision has caused continuous interest and research on this topic. Therefore, there have been active developments related to the regulations/product property evaluations and systems that deal with this type of collision. Rear-end collisions are less likely to be fatal to passengers than frontal and side collisions, but occur at a higher frequency. This has caused a gradual increase in interest due to the raised societal expenses. In order to regulate this, product property evaluation has been progressing centered around insurance institutes. Since 2004, both IIHS & THATCHAM have conducted static and dynamic assessments and released the results.

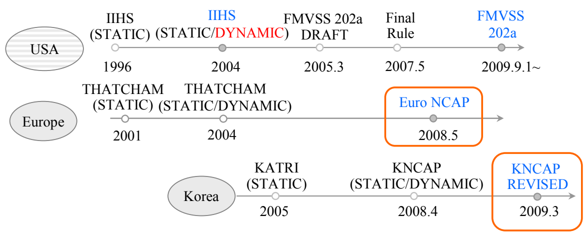


Figure 1. Regional specific neck injury assessments/product property status

As shown on Figure 1, EURONCAP has developed new evaluation criteria and has been conducting assessments for rear-end collision neck injuries since 2008. They have done so by adding supplements to the existing IIHS. KNCAP imported EURONCAP evaluation criteria and adjusted them to Korea circumstances. KNCAP has been conducting assessments since 2008, and enhanced injury criterion will be enforced in 2009. EURONCAP and KNCAP use combined ratings system for frontal, side, and rear-end collisions. They report the assessment results, with each category separately evaluated and recorded. This research supplements the existing IIHS criteria, identifies the enhanced EURONCAP and KNCAP injury criterion regarding seat characteristics, and introduces developments of improved system.

Regional neck injury property evaluation status

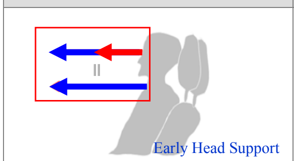
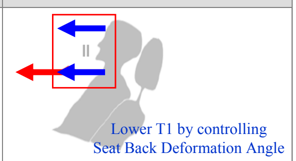
IIHS's existing dynamic performance evaluation factors of Fx, Fz, T1, HRCT are not enough to represent actual neck injuries in rear-end collisions. To supplement, EURONCAP & KNCAP added 3 criteria as shown on Table 1: NIC, NKm, HRV.

Table 1.
Product property evaluation status

	IIHS (North)	KNCAP	EURO NCAP
Dynamic Injury Criteria	• Fx • Fz • T1 • HRCT 16km/h	• Fx • Fz • T1 • HRCT • NIC • Nkm • HRV 16km/h	• Fx • Fz • T1 • HRCT • NIC • Nkm • HRV 16km/h 16km/h 24km/h
Rating	GOOD ACCEPTABLE MARGINAL POOR	★★★★★ 4.9~6 ★★★★ 4.0~4.9 ★★★ 3.1~4.0 ★★ 2.2~3.1 ★ 0~2.2	GOOD 3.00~4.00 MAGINAL 1.50~2.99 POOR 0.00~1.49

The general concept for neck injury reduction, currently used in most of the models, utilizes forward protrusion of the headrest structure upon collision. This provides head support and creates affinity between torso acceleration and head acceleration by raising the head's acceleration, as shown on Table 2. This system generally has superior HRCT(HeadRest Contact Time) but has the tendency to show unfavorable T1 accelerations. Although the system introduced by the other concept is somewhat slower to support the head, the head's acceleration is matched by lowering the torso's acceleration. This case shows superior T1 but has the tendency to show unfavorable HRCT.

Table 2.
Basic concept of neck injury reduction

Increase Head acceleration	Reduce Torso Acceleration
	
• Increase head acceleration to reduce relative acceleration differences between head and torso	• Reduce Torso acceleration to reduce relative acceleration differences between head and torso
• Most of Current Re-active H/rest system	• AUTOLIV whips

METHORD

Competition-Car Evaluation Study

Analysis of Table 3, the competition-car evaluation result, shows T1 and HRV(Head rebound velocity) values to be most unfavorable among the 7 dynamic injury criteria. Since the dynamic performance factor is derived by selecting a superior score between T1 and HRCT and then totaling up that score with the rest of the 5 categories in neck injury assessment, improvement to the HRV value is the most important.

Table 3.
KNCAP neck injury evaluation status of competition-car

	SEAT	Dynamic								STATIC + DYNAMIC (%)	RATING
		NIC	Nkm	HRV	FX	FZ	OR		Total		
							T1	HRCT			
1	NON AHR	1.13	1.27	0.87	1.5	1.5	0	1.5	7.77	83.7	5★
2	Whips	1.5	1.5	1.5	1.5	1.5	1.5	0	9	99.6	5★
3	ACTIVE	0.85	0.67	0.58	1.2	1.18	0.55	1.32	5.8	68	4★
4	NON AHR	1.5	1.16	1.14	1.5	1.11	1.35	1.5	7.91	85	5★
5	ACTIVE	0.83	0.9	0.82	1.5	1.5	0	1.5	7.05	79.3	4★
6	NON AHR	1.27	0.82	0.4	1.14	1.11	0.13	1.38	6.12	71.2	4★
AVERAGE		1.18	1.05	0.89	1.39	1.32	0.59	1.20	7.03	78.6	4★

Table 4.
KNCAP evaluation status of tested seats

	SEAT	Dynamic								STATIC + DYNAMIC (%)	RATING
		NIC	Nkm	HRV	FX	FZ	OR		Total		
							T1	HRCT			
1	AHR	0.69	1.31	0.72	1.5	1.5	1.5	1.5	7.22	82.2	5★
2	AHR	1	1.08	0.74	1.5	1.5	1.38	1.5	7.32	83.2	5★
3	Non AHR	1.39	1.16	0.71	1.5	1.5	1.24	1.5	7.76	84.3	5★
4	Non AHR	1.29	1.05	0.86	1.5	1.5	0.9	1.5	7.7	82.9	5★
5	AHR	1.39	1.08	0.67	1.5	1.5	0.91	1.5	7.36	83.8	5★
6	AHR	1.24	1.23	0.75	1.48	1.5	0.39	1.5	7.7	82.6	5★
AVERAGE		1.18	1.21	0.66	1.48	1.46	0.82	1.47	7.44	83.1	5★

As shown on Table 4, evaluation results of HMC models show weak HRV and an insufficient margin, although 5□ has been obtained. To obtain the above results, numerous tests were performed to each model. It can be confirmed that the best way to improve neck injury assessment is to boost the HRV value and back frame deformation characteristics, which can be verified through competitive analysis of a superior HRV valued vehicle.

HRV (Head Rebound Velocity) value generally occurs when the elastic strain energy stored in seat is converted to kinetic energy in the dummy after maximum acceleration of sled has been achieved. Maximum restitution rate generally occurs at the point where the dummy's head and headrest separate, or immediately after. To improve the HRV value: thicken the seat's pad, since the seat absorbs the dummy's inertial force ; widen the seat back's frame;

increase the headrest's stay strength; induce plastic deformation in the seat back to remove elastic energy. Figure 2, below, shows HRV value obtained through the evaluation of HMC & competitors' seats. All of the seats have similar HRV values except "A seat."

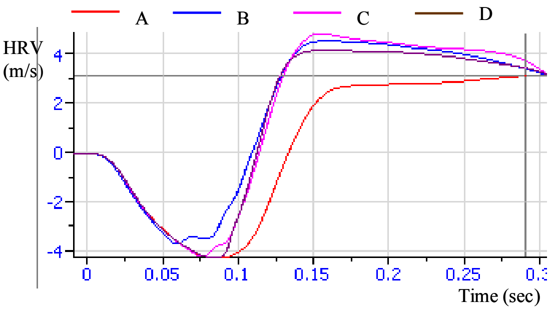


Figure 2. HRV Evaluation Graph

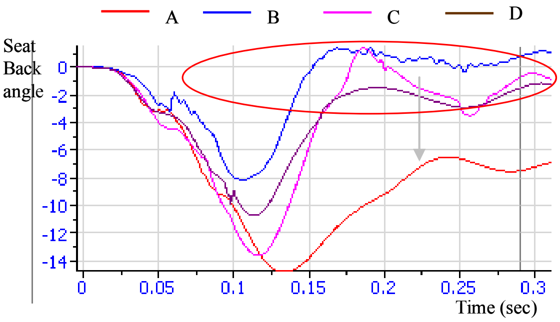


Figure 3. Deformation angle of seat back

	A	B	C	D	Average seat
Max Deform Angle	14.6	8.2	13.8	10.7	11±1˚
Deformation Angle at 300ms	7.24	0	0.5	1.2	0~1˚
System	Whips	Passive	Re active	Passive	-
HRV (3.2m/s~4.8m/s)	3.2	4.3	4.8	4.2	4.13

Table 5. Benchmarking test results

Analysis of Figure 3 and Table 5 shows the notable differences are from the seat back angle's displacement volume. "A Seat" had the largest seat back displacement along with higher permanent displacements for the seat-back. This shows the use of a structural system that absorbs the dummy's energy using plastic deformation of the seat back upon collision.

System Design

The development of a structural system that can control the seat back's deformation in a rear-end collision is necessary. This system should also meet HMC's seat mountable conditions. As shown on Figure 4 and Figure 5, the system operates only in collisions and is in a locked position during general operation.

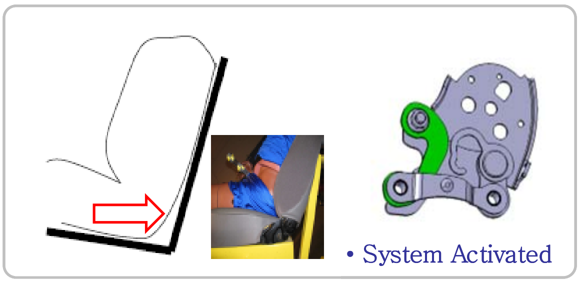


Figure 4. System activated in rear-end collision

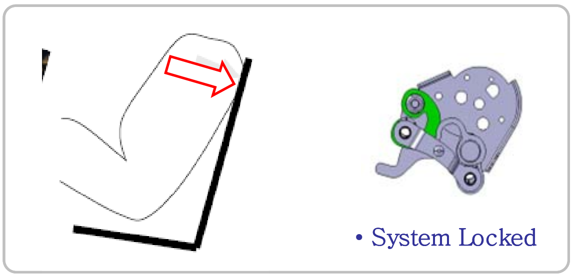
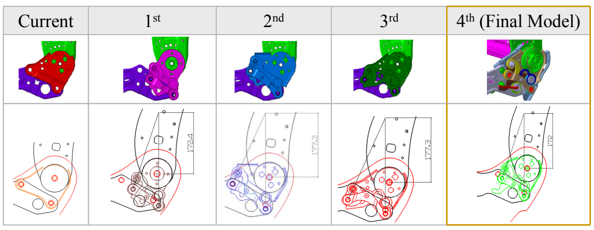


Figure 5. System locked in general conditions

Design model improvements were executed during phase 4 in considerations of package conditions, collision conditions, general usage conditions, and optional applications on current frames, et cetera. The final Design Model specification drawing has been released as shown on Table 6.

Table 6. Revised model of Reduction System



The system(Whips: Whiplash Injury Protectin System) should work as below in figure 6. The corresponding detachable side cover for the system operations is also shown.

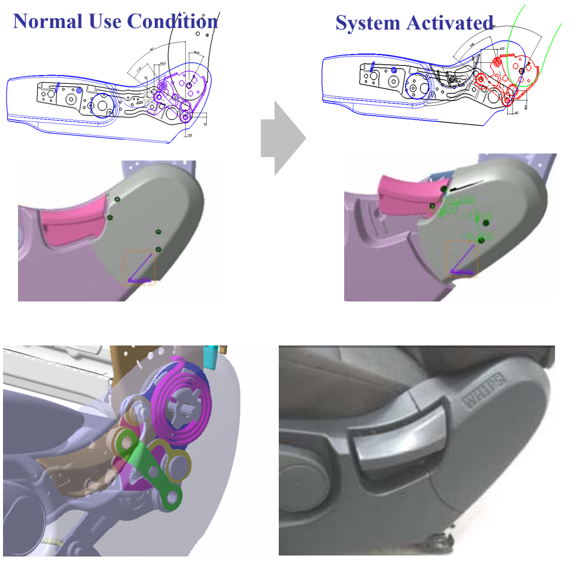


Figure 6. Detachable side cover concept & actual sample for Whips

System Analysis

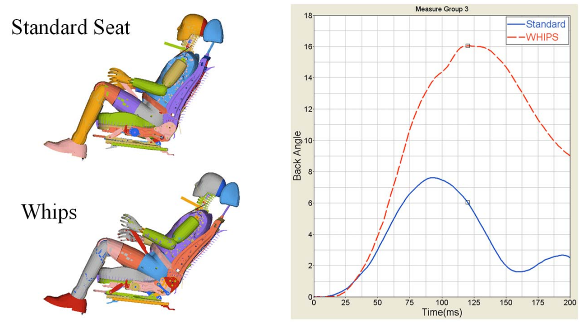


Figure 7. Seat Back's Maximum Displacement in Rear-End Collision with Whips & Standard seat

The designed model was used for the neck injury analysis. The system's parts were adjusted, as it wasn't functioning during the analysis phase 1. The system was functioning well, however, during the analysis phase 2 with some modification. As shown in Figure 7, the following were confirmed: the seat back's rearward maximum displacement with Whips exceeded the standard seat deformation angle by 8 degrees. As shown in Figure 8, HRV **improved by 0.75 points** compared to the existing value because of induced plastic deformation within the system, and the dynamic performance improved by 0.95 points, 4.5 □ → 5.0□ (0.5□↑).

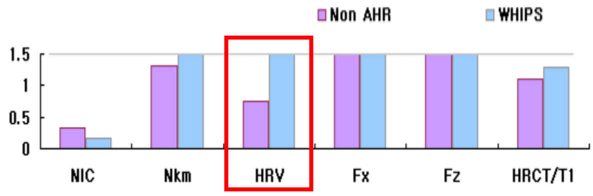


Figure 8. Analysis result with Standard seat and Whips

Evaluation Result

The improved model, which is based on the analysis results of the Whips application, was used as a final evaluation. An evaluation was conducted, and the system operated normally, as shown in Table 7.

Table 7.
System condition of Before/After crash

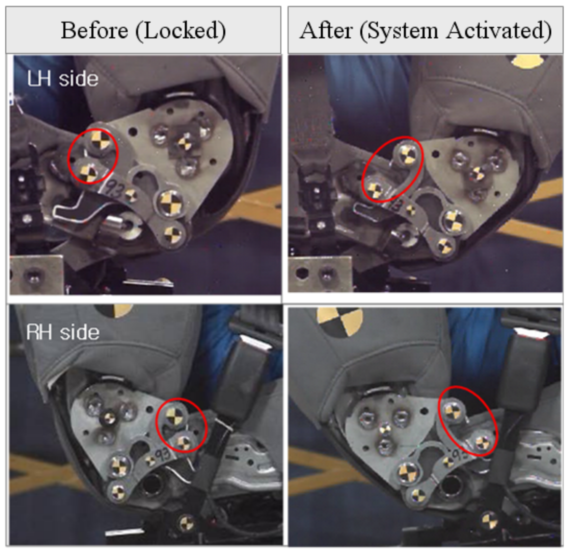


Table 8.
Evaluation results of KNCAP Whips

		HRV	FZ	%	Rating
Current standard seat	-	0.71	1.5	84	5.0★
Current standard seat with conventional active headrest	Active Headrest	0.72	1.5	82	5.1★
Whips system Test 1	Whips system applied	1.5	0.95	83	5.4★
Whips system Test 2	Volvo Headrest Was applied	1.5	1.5	95	5.6★
Whips system Test 3	Headrest blower modified	1.5	1.5	96	5.7★

Table 8. shows the evaluation result of the Whips application. On the first evaluation, HRV value improved but Fz value worsened. Contrasted with the existing standard seat, the head's tensile force increased and the seat back's displacement value

came close to 16 degrees when the Whips system was applied. Whips applied HRV's characteristic curves are shown in Figure 9. Definite differences can be confirmed when compared to the standard (passive system) seat.

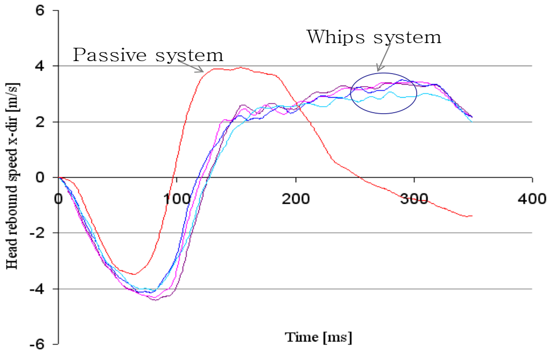


Figure 9. Evaluation result of HRV with standard seat and Whips

The result was a worse value for Fz because the Whips system has a greater seat back deformation angle than the standard seat, as shown in Figure 10.

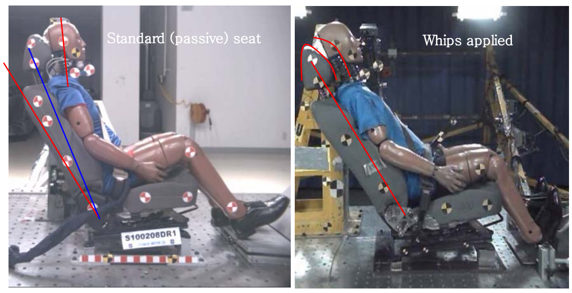


Figure 10. Standard vs Whips applied dummy motion

Next, a trend validation test was performed using the Volvo headrest. The result was a good score. It can be deduced from this second result that an improvement to Fz value is possible if using the appropriate heardrest shape, internal structure shape, stays, et cetera.

For the third test, as shown in Figure 11, the shape of the headrest's blower area was improved. The original round shape was flattened out and the stay strength was increased.

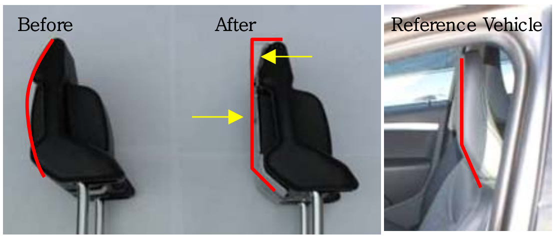


Figure 11. Headrest inner part shape improved

Additional validation is planned such as severe rear crash, frontal crash, luggage block retention, et cetera.

CONCLUSIONS

This research was a study on the fundamental approaches to neck injury reduction. Minimization of the head and torso's relative motion is the basis of neck-injury reduction. Two basic systems were studied: a system that creates forward protuberance of the headrest to increase the head's acceleration and minimize the torso acceleration variances, and a system that minimizes the torso acceleration and minimizes the head acceleration variances.

Frame behavior characteristics and HRV correlation analysis were conducted by analyzing the evaluation results of HMC seats and competition-car seats. The most influential factor on HRV value improvement was the seat's capacity to absorb the dummy's collision energy, especially the frame's ability to absorb energy was founded to be critical.

Development of a system that induces plastic deformation to absorb collision energy, therefore improving HRV, was confirmed. A robust system was designed by applying a Reduction System that can respond to the new injury criteria of KNCAP and EURO NCAP for HRV, Nkm, NIC, et cetera.

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