ASSESSMENT OF 12 YEARS KNCAP PERFORMANCES AND PLAN FOR ELDERLY OCCUPANT PROTECTIONS

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ABSTRACT

In 1999, Korea government has been established KNCAP program to promote vehicle safety enhancement and to reduce road traffic fatality. Currently, total 8 test protocols are available to evaluate vehicle safety performances including the two types of frontal crash test and side pole test. As results of the reinforcement of safety issues, the average KNCAP vehicle safety rate reaches about 4.5 star ratings. Furthermore, from 2010, the overall crash performance assessment rating system was adapted to clear understanding of the KNCAP results with the voluntary labeling system which similar to US labeling system.

However, in terms of elderly occupant's safety, the fatality rate is much higher than other age group. Conjunction with the current Korean elderly occupant protection research program, which initiated by the government resource 5 years ago, the assessment tool, may also include protecting a vulnerable road user, especially elderly drivers or occupants.

Recent researches show that the elderly occupant rib cage is relatively weak and fragile compared to the nominal adult age group. The current larger mass and stiff front structure of vehicle design required pretensioner belt system with relatively higher load limiter. When this belt restraint system with airbag were subjected to the anthropometric dummies such as Hybrid III 50%tile male or 5%tile female dummy, the injury performance were in excellent rate thus expected in good occupant protection in the real traffic accidents. However, in the real field, the fatality of elderly is more than 10 times higher than other age groups. The most frequent injuries are thoracic trauma, rib fractures due to the severe rib deflections.

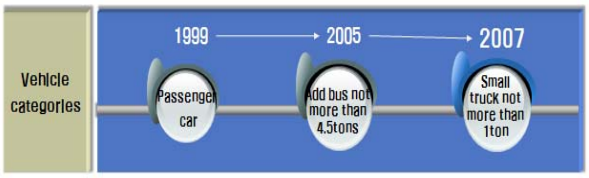
The objective of our study was investigate rating criterion for pretensioner and load limiter performance for elderly occupant protections to define requirements for an optimal belt loading forces, and to quantify the benefits for elderly occupants within KNCAP testing system.

INTRODUCTION

The Korean New car Assessment Program (KNCAP) has been one of the most market influencing factors in the aspects of safety issues as well as industries safety technology adoptions in their new vehicles. The results of KNCAP ratings were published twice a year and also provide information on proper use of safety devices in order to enhance user's awareness and correct understanding on safety related devices such as airbag, ABS and seat belts. At the beginning, KNCAP test protocol and evaluation methods are similar to the previous USA NCAP and only passenger car category was tested. In the motor vehicle management act (Article 32-2), the KNCAP has been legal basis in 2002.

In 2005, up to 4.5 tons of buses and vans were included in the K-NCAP and not more than 1.0 ton truck was added as a test vehicle in 2007. This means that 87% of all buses and 72 % of trucks and 100% of passenger vehicles can be covered and evaluated safety performances within KNCAP

system. Thus KNCAP covered 95% of all possible vehicle types. The Figure 1 shows that the expansion of vehicle category in KNCAP.



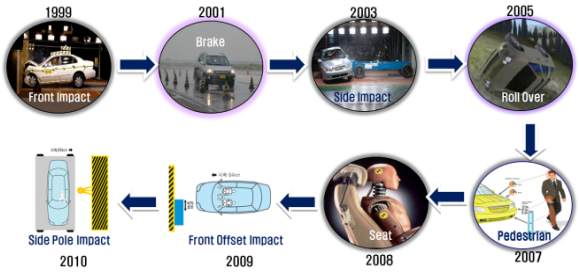
The distribution of bus not more than 4.5 tons was 87% of all buses.

The distribution of truck not more than 1.0 ton was 72% of all trucks.

KNCAP in the vehicle categories shall be covered 95% of all vehicles.

Figure 1. Vehicle categories in KNCAP

The test items were only the full wrap frontal crash test and braking test until 2002, however, with 55kph impact speed side crash test was added in 2003. In 2005, static roller test for roller protection and static measurements of head restraint's heights and backset test were introduced as a part of KNCAP. Since the majority of traffic fatalities were results from car to pedestrian accidents, the pedestrian head impact test and leg impact test were added in 2007 and 2008 conjunction with WP29 GTR harmonization. This year, the pedestrian head test will be added to evaluate the protection of pedestrian. In 2008, the head restraint test was updated with the dynamic test. Recently, 64km/h frontal offset test was also added to insure the front seat occupant protections in 2009. Finally, last year as an optional test, 90 degree side pole test was adopted as shown in Figure 2.



※ The largest share of fatalities in traffic accident is pedestrian as 36%.

※ Small truck is excluded from the side impact and pedestrian test.

※ Side Pole Impact test is additional test by car maker (2 point)

Figure 2. Expansion of KNCAP Items

For clear understanding of test results and degree of safety performance, in 2010, the overall crash performance rating system has been introduced and the total rating system including the active safety features will be adopted in 2013.

Enhancement of Frontal Crashworthiness

2010 KNCAP, the total 12 new vehicle were tested including 3 imported passenger vehicles. The selections of vehicle are based on the untested vehicle, sale volumes. The base (or minimum safety devices) design vehicle of the selected vehicle model will be tested. The all 12 KNCAP test result is shown in Table 1.

Table 1. 2010 KNCAP Test Results

2010		Test Items								
		Crash Test							Pre-Safety Test	
Class	Vehicle	Full Frontal	Offset Frontal	90° Side	Whiplash	Side Pole	Overall	Pedestrian	Rollover	Braking Distance (Dry / Wet)
SC	GM-D **Matis**	★★★★★ (15.1, 94%)	★★★★★ (14.3, 89%)	★★★★★ (15.0, 94%)	★★★★ (4.8, 80%)		Class 1 (49.2, 91%)	★★★★ (20, 67%)		45.7m 50.7m
C	R-S **SM3**	★★★★ (12.5, 78%)	★★★★★ (14.2, 89%)	★★★★★ (14.1, 88%)	★★★★ (4.4, 73%)		Class 2 (45.2, 84%)	★★★ (13, 43%)		45.3m 47.8m
	Hyundai **Avante**	★★★★★ (15.8, 99%)	★★★★★ (14.8, 93%)	★★★★★ (15.8, 99%)	★★★★★ (5.0, 83%)	2.0, 100%	Class 1 (53.4, 99%)	★★★ (14, 47%)		41.5m 42.6m
M	Kia **K5**	★★★★★ (15.7, 98%)	★★★★★ (15.0, 94%)	★★★★★ (15.4, 96%)	★★★★★ (5.2, 87%)	2.0, 100%	Class 1 (53.3, 99%)	★★★ (18, 60%)		43.3m 43.7m
	R-S **SM5**	★★★★★ (13.4, 84%)	★★★★★ (14.7, 92%)	★★★★★ (15.8, 99%)	★★★ (3.8, 63%)	2.0, 100%	Class 1 (49.7, 92%)	★★ (9, 30%)		43.1m 44.6m
	Hyundai **Sonata**	★★★★★ (16.0, 100%)	★★★★★ (15.2, 95%)	★★★★★ (15.3, 96%)	★★★★★ (5.1, 85%)	2.0, 100%	Class 1 (53.6, 99%)	★★★ (13, 43%)		45.8m 46.7m
M (RV)	Kia **Sportige**	★★★★★ (15.2, 95%)	★★★★★ (14.5, 91%)	★★★★★ (15.6, 98%)	★★★★★ (5.3, 88%)		Class 1 (50.6, 94%)	★★★★ (21, 70%)	★★★★ (15.0%)	42.5m 43.5m
	Hyundai **Tucson**	★★★★★ (14.8, 93%)	★★★★★ (15.2, 95%)	★★★★★ (15.0, 94%)	★★★★★ (5.3, 88%)		Class 1 (50.3, 93%)	★★★ (15, 50%)	★★★★ (16.4%)	44.1m 48.1m
L	Kia **K7**	★★★★★ (15.2, 95%)	★★★★★ (15.5, 97%)	★★★★★ (16.0, 100%)	★★★★★ (5.0, 83%)	2.0, 100%	Class 1 (53.7, 99%)	★★★ (18, 60%)		45.8m 47.6m
	Lexus **ES350**	★★★★★ (16.0, 100%)	★★★★★ (14.6, 91%)	★★★★★ (16.0, 100%)	★★ (3.0, 50%)		Class 1 (49.6, 92%)	★★ (10, 33%)		45.2m 49.2m
	Benz **E220 CDI**	★★★★ (12.2, 76%)	★★★★★ (14.3, 89%)	★★★★★ (16.0, 100%)	★★★★ (4.5, 75%)	2.0, 100%	Class 1 (49.0, 91%)	★★ (9, 30%)		42.2m 46.2m
	Audi **A6**	★★★★ (12.9, 81%)	★★★★★ (15.1, 94%)	★★★★★ (15.4, 96%)	★★★ (3.6, 60%)		Class 1 (47.0, 87%)	★ (0, 0%)		38.6m 42.7m

In the frontal crash test, for driver side occupant, the probability of severe injury was 16.4% improvement compared with that of 1999 to 2003 average results. In terms of star rating in 2010, 0.3 stars were increased. On the passenger side occupant, the likelihood of severe injury can be reduced up to 51.6% compared with results of 1999 through 2003 as shown in Table 2 and Figure 3.

The offset frontal test, all 12 vehicles achieved 5 stars but, in the full wrap rigid barrier test, 2 imported vehicles get 4 stars. But 1 domestic vehicle gets 3 star ratings (after re-test procedure, get 4 star).

Table 2. Frontal Occupants Safety Improvements (avg. 1999-2003 vs. 2010)

		Frontal Crash		Improvement (% or Star)	Reduction %
		'99-'03	'10		
Driver	Probability of Severe Injury(%)	18.3	15.3	3	16.4
	Avg. Star	3.8	4.1	0.3	7.9
Front passenger	Probability of Severe Injury(%)	25.0	12.1	12.9	51.6
	Avg. Star	3.2	4.3	1.1	34.4
Sum of Probability of Severe Injury(%)		21.6	13.7	8.0	37.0

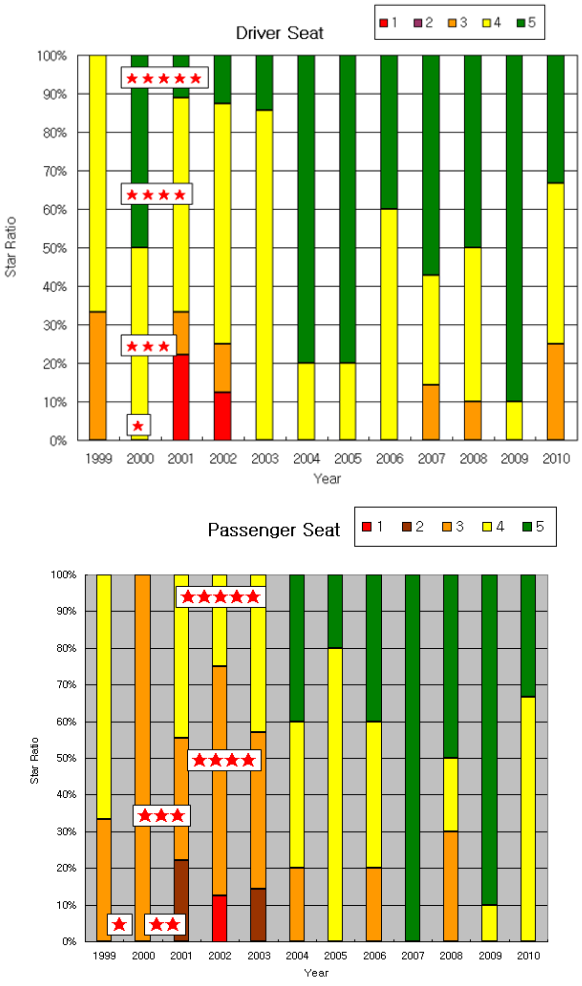


Figure 3. Trends of Star rating in Frontal Crash

TRENDS OF KOREA TRAFFIC ACCIDENTS AND ELDERLY OCCUPANT INJURY PATTERNS

Competition among car makers for the safer performances in line of KNCAP, the number of fatality and serious injury can be reduced. According to Nation police reports, the fatality of traffic accidents is gradually reduced year by year. Although the significant number of total registered vehicle is increased annually, in 2009, the total death from the traffic accidents was 5,838 (2008: 5,870) as shown in Figure 4. Results from the increased total traffic volume, the number of traffic accident and injury is still gradually increased every year.

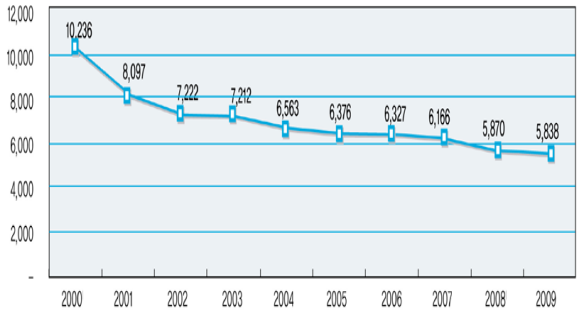


Figure 4. Trends of Traffic Fatality in Korea

The pedestrian fatality was about 35% while the fatality from car-to-car accident is the most frequent source of fatality, 43.6% (2,546). The remaining 21% of fatality was from the single vehicle involved accidents as shown in Figure 5.

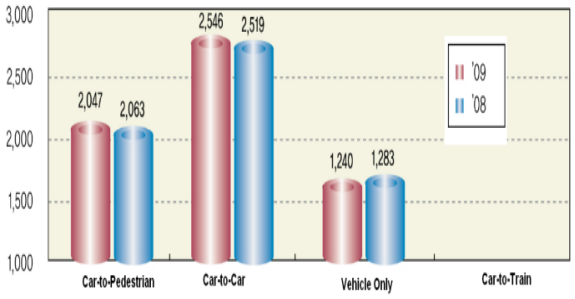


Figure 5. Accident Type of Traffic Fatality

Increase of Elderly Involved Traffic accidents

From 2005 national census, the population of 65 years and more (65+) was reached 4.3 million (9.1%) and entered aging society. Due the current extremely lower birth rate, the aging rate is rapidly increased. The most demographic forecasts indicate the proportion of Korean over 65 years of age by the year 2019 will be more than 14% of total

population as an aged society.

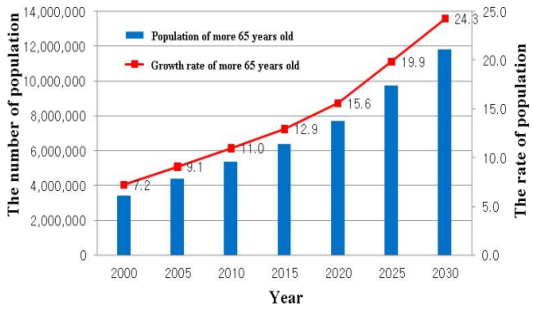


Figure 6. Elderly Population in Korea.

Therefore, it will become increasingly more important that safety standards or other assessment methods be optimized to mitigate elderly casualties. Unlike EuroNCAP, KNCAP does not account abnormal behaviors of occupant or safety devices during the crash test in the scoring system. The modifier was not adopted in KNCAP due to the possible argument of subjective opinions on the application of modifier.

Currently, in KNCAP 50%tile Hybrid III dummy was used to evaluate vehicle safety performances. Now, there are no criteria or weighting factors to be considered other than Hybrid III standard male dummy. Since, the number of elderly drivers (and/or passengers) or small frame of female drivers (and/or passengers) are continuously increased. by every year. Elderly drivers and passengers have a disproportionately higher crash involvement rate and commonly sustain more severe injuries than the general population.

From the National Police Reported Accident Data for the years 1994 to 2006, the fatality of the age group 61 and older (61+) was continuously increased 1,748 (17.3%) to 2,136 (33.8%). Still, the majority of elderly fatality is coming from the pedestrian casualty, however, the number of fatalities and seriously injured elderly occupants are rapidly increasing year by year.

In 2009, the elderly traffic causality was 1,826. It is 31% of total fatality. If consider the only fatality of elderly occupant (in vehicle), the ratio is 15%.

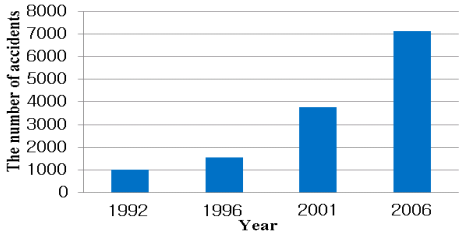


Figure 7. The Number of Korean Elderly Involved in Accidents.

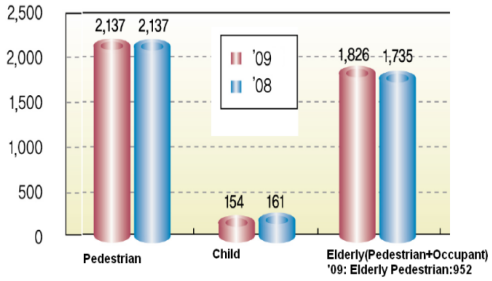


Figure 8. Fatality of Elderly Accidents

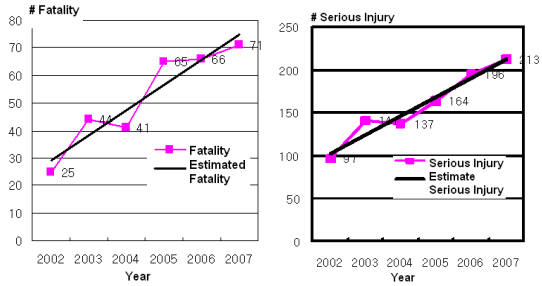


Figure 9. Estimated Trends of Fatality and Serious Injury of Elderly Accidents

Therefore, providing mobility as well as improvement of safety for older occupants is essential for aging society. To provide the safety for the elderly occupants, it will be necessary to review the injury criteria and safety standards to mitigate elderly casualties. Currently, the injury criteria in KMVSS are determined by Hybrid III 50%tile dummy readings similar to other countries.

INJURY PATTERNS OF THE ELDERLY OCCUPANTS

The risk curve, based on serious casualty data, exaggerates older drivers' crash involvement because of the 'frailty bias'. Because older people are more readily injured by a given physical impact, proportionally more of their total crashes have serious casualty outcomes. Many of research suggest that around one-half of the heightened

fatality risk of drivers aged 75 years and more might be due to frailty rather than to unsafe driving practices. The same correction can be made to older drivers' involvement in non-fatal serious injury crashes.

Aging is a complex process which yields numerous mental and physical changes. In the present study, only physical changes were considered (e.g., geometrical, material, and structural). A number of studies have shown that, with increasing age, the energy-absorbing capacity of body structures generally declines.

Burstein, Reilly, and Martens concluded that there was a 5% decrease in the fracture strain per decade in the femur and a 7% decrease for the tibia. Zhou, Rouhana, and Melvin reviewed a number of aging functions of the femur bone and showed that the maximum bone strength occurs at approximately 35 years of age. The bone strength then begins to decline, with the rate of decline increasing significantly after 60 years of age. Zhou et al. also determined that the human soft tissues follow a similar trend.

Although older drivers are involved in relatively few collisions due to limited exposure, once involved in a crash they are more likely to sustain severe injuries or death (Cunninghan *et al*.). Several studies have confirmed that as people age, they are more likely to sustain serious or fatal injuries from the same severity crash (Evans, Evans, Bedard *et al*., Mercier *et al*., University of Michigan, Wang, Peek-Asa *et al*., Li *et al*.).

Elderly drivers and occupants are especially at risk of thoracic region injuries due to increased bone fragility (University of Michigan, Wang *et al*., Wang, Augenstein *et al*., Foret-Bruno, Schiller, Sjogren *et al*., Bulger *et al*.).

Results from S.C Wang, the head injury is the most frequent in younger age group, while the older age group is suffered from mostly thoracic injury as shown in Figure 10. From the NASS (1993-1996) data, the more old age group, the more numbers of rib fracture is occurred in the frontal collision.

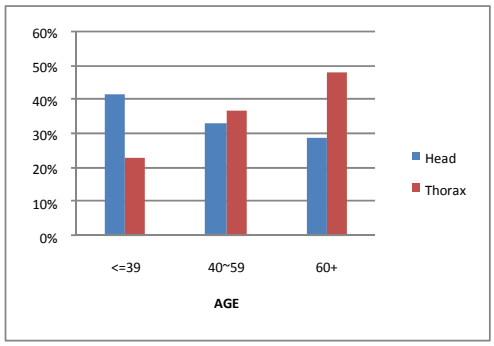


Figure 10. Incidence of Thoracic and Head Injury by Age Group. (S. C. Wang).

Korean Elderly Occupant Injury Patterns

From the Korea national accident database (2000-2007), the elderly occupants exposed higher risk in thorax, head and abdomen. The thoracic injury risk is 2.6 time higher than other age groups. The head injury is 1.3 time higher and abdomen injury is 1.9 time higher. The elderly male abdomen injury is 26.2% higher than that of female elderly occupant.

But, female elderly has higher potential risk in head and lower extremity 57% and 11.6% respectively more than those of male elderly. In seating position, driver side is 2.9 times more suffered thorax injury compared with 25 - 54 year old age group. Regardless the type of vehicles, the thorax injury of the elderly occupant is more than 1.7 - 2.1 times more frequently occurred.

The elderly seated in SUV and RV vehicles are more injured than sedan type vehicle during the car-to-car frontal collisions. The seat belted elderly is more suffered thorax, abdomen and upper extremity injuries than other age groups. However, compared with non belted occupants, there are no differences in terms of injury between different age groups. Even the airbag equipped vehicle, still elderly occupants exposed 12.9% more sever thorax injury compared with other age group.

2009 KNCAP FRONTAL CRASH TEST ANALYSIS

Ten vehicles from four Korean auto makers and two foreign auto makers were tested for KNCAP program in 2009. The test results and the star ratings for the vehicles are represented in Table 3.

Table 3. 2009 KNCAP Frontal Test Results

Vehicle	Class	Occupant	Full wrap Frontal Crash		Offset Frontal Crash	
			Star Rating	Probability of Injury	Star Rating	Points
Kia Soul	Sub-mid	Driver	★★★★★	8 %	★★★★★	15.1
		Passenger	★★★★★	9 %	★★★★★	14.4
Kia Forte	Sub-mid	Driver	★★★★★	9 %	★★★★★	14.2
		Passenger	★★★★★	9 %	★★★★★	14.1
GM Daewoo Lacetti	Sub-mid	Driver	★★★★★	9 %	★★★★★	15.6
		Passenger	★★★★★	8 %	★★★★★	13.6
Hyundai Genesis Coupe	Medium	Driver	★★★★★	8 %	★★★★	12.1
		Passenger	★★★★★	10 %	★★★★★	14.8
Benz C200K	Medium	Driver	★★★★	19 %	★★★★★	13.9
		Passenger	★★★★	17 %	★★★★★	14.2
Honda Accord	Medium	Driver	★★★★★	8 %	★★★★★	15.2
		Passenger	★★★★★	6 %	★★★★★	15.7
Ssangyong Chairman W	Large	Driver	★★★★★	7 %	★★★★★	15.2
		Passenger	★★★★★	7 %	★★★★★	15.2
Hyundai Equus	Large	Driver	★★★★★	7 %	★★★★★	13.6
		Passenger	★★★★★	7 %	★★★★★	14.4
Kia Sorento	Large (SUV)	Driver	★★★★★	9 %	★★★★★	14.8
		Passenger	★★★★★	9 %	★★★★★	14.9
Hyundai Veracruz	Large (SUV)	Driver	★★★★★	10 %	★★★★★	13.8
		Passenger	★★★★★	7 %	★★★★★	14.0

The HIC, Chest g's and Chest compression are represented in Figure 11 - Figure 12. All vehicles scored 5 stars in driver and passenger except one imported vehicle which was not designed for the full wrap barrier test. In the offset barrier test, only one 2 door domestic vehicle's driver side was not achieved 5 stars. Compared with previous year's (1999-2008) results, the safety performances were dramatically improved.

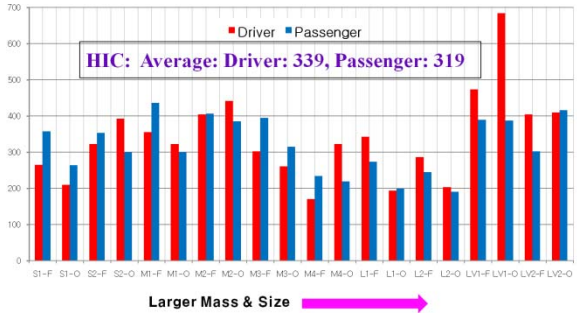


Figure 11. HIC Distribution of 2009 KNCAP

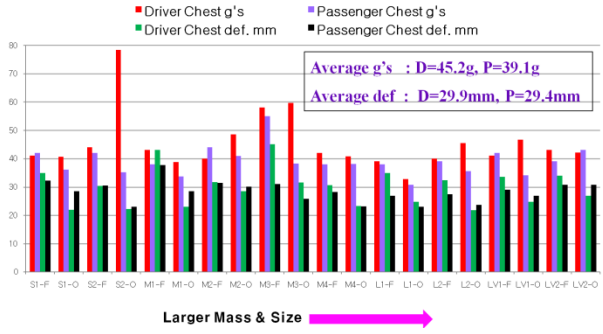


Figure 12. Chest Injury Distribution of 2009 KNCAP

From the dummy injury results, average of driver and passenger side HIC were 339 and 319 respectively. The 48km/h regulation required less than 1,000 HIC values. For the chest deflection case, while the 48km/h regulation required 76mm as a limit, but the average of chest deflection were 29.9mm and 29.4mm in driver and passenger side respectively. Even though more severe impact condition, the results shows a quite low chance of head and chest injury risks.

The next two Figures show the seatbelt loading forces measured in the Hybrid III 50%tile male dummy during the test.

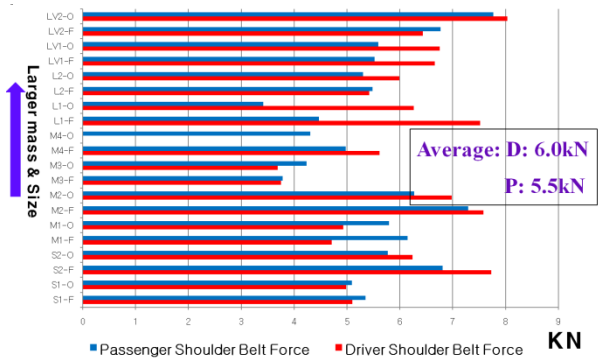


Figure 13. Shoulder Belt Forces of 2009 KNCAP

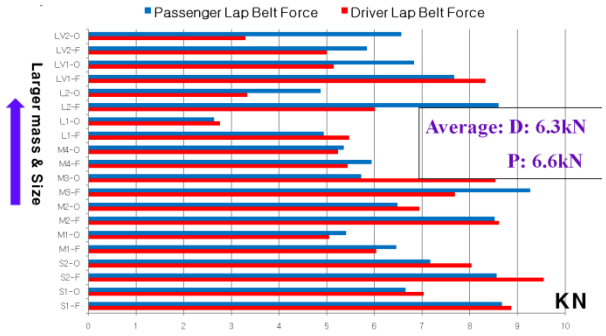


Figure 14. Lap Belt Forces of 2009 KNCAP

Results from Trosseille researches, the chest injury risk of AIS+3 for 40 year old occupants reveal less than 10% up to 6kN of shoulder belt force. However, the risk is dramatically increased. For the same level of shoulder belt force, 50 year old can be exposed 35% of risk and for 70 year old occupant, it can be reached up to 95% of AIS+3 thoracic injury.

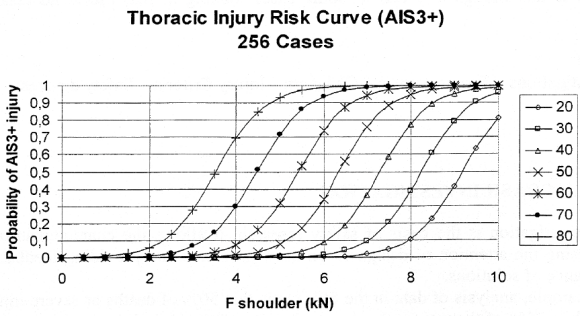


Figure 15. Probability of severe thoracic injuries (AIS3+) depending on the shoulder belt force and the occupant age (Trosseille)

Currently, the Hybrid III 50%tile male dummy is only one dummy regulatory body accepted. To protect elderly occupants from the thoracic injury during the frontal crash events, the further improvement of the chest deflection criteria is not sufficient enough without the controlling the stiffer seat belt force level.

PLANS FOR ELDERLY OCCUPANT THORCIS INJURY PROTECTIONS

The load limiter in the 3-point belt is intended to limit the forces exerted by the belt and thus the values for the thoracic load. Already in the early 1970 load limiters were applied in serial production, at that time, of course, without airbag. Their benefit has been demonstrated by accident analyses. Today load limiters are mostly applied in combination with an airbag to achieve an optimum alignment of the restraint system.

- Adoption of Modifier for Higher Belt Forces in KNCAP Rating System

From the 2009 KNCAP results, the average seatbelt force is about 6kN. From our researches and other previous researches, to protect elderly occupant from the thoracic injury, the load limiter should be in the range of 1.5 kN – 2.0 kN. Appling the modifier in the scoring system, this may lead the lowering seat belt force loadings as well as stimulating development of an adoptive restraint system as a universal design both beneficial for the standard size male occupant and the vulnerable occupants.

- Certification of 'Elderly Friendly Vehicle'

Now, in Korea, all applicable goods or productions can be achieved the unified Korea Certification (KC). The Korean government previously operated 170 certification systems. However, this excessive number of systems confused consumers and created an undue burden for companies in terms of time and expense. Consumers can choose products that comply with nationwide standards with regard to safety, health, quality and environmental impact.

Currently the requirement of 'Elderly Friendly Vehicle' for KC mark is investigated based on the research works.

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