REVIEWS OF SIDE KNCAP ON THE VEHICLE STRUCTURES AND OCCUPANT PROTECTIONS

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ABSTRACT

The Ministry of Construction and Transportation of Korea (MOCT) has been conducted the side impact crash tests for the new passenger vehicles as a Korean New Car Assessments Programs (KNCAP) and provided crashworthiness and safety information to the public since 2003. Eleven compact passenger cars, four medium passenger cars and three SUVs and two Van type vehicles were evaluated according to the Korean side impact test protocols. Based on the test results, the most dominant factor for good star rating was the rib deflections of EuroSID-I. The next main factors were abdominal forces and pubic symphysis forces. The least influencing factors were viscous criteria and head injury criteria. Since KNCAP side impact program has been introduced, year after year, the newer vehicles gained the better grades. Especially, all SUVs and Vans with R-point over 700 mm get five stars due to higher side sill heights.

The main purpose of this study is to evaluate the trends of strength of vehicle structure changes, interior package design parameters, protection zone of side impact airbag or type of airbags to add additional counter measurements of side impact performances, such as a pole type impact test.

INTRODUCTION

In 1999, Korean government established the Korean New car Assessment Program (K-NCAP) after 3 years research work. The main purpose of KNCAP is that to not only promote buying a safer car but encourage auto makers to undertake more efforts in building safer cars by publishing test results every year. KNCAP 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, frontal KNCAP test protocol and evaluation methods were identical to USA NCAP and only passenger car category was tested. In 2005, up to 4.5 tons of small trucks and vans were included in the K-NCAP.

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 2004 then in 2005, static roller and head restraint test were now part of K-NCAP as shown in Table 1. This year, the pedestrian head test will be added to evaluate the protection of pedestrian. Next year, 2008, the pedestrian leg test and dynamic head restraint test will be conducted. Until 2011, the test items will be expanded up to 10 test items.

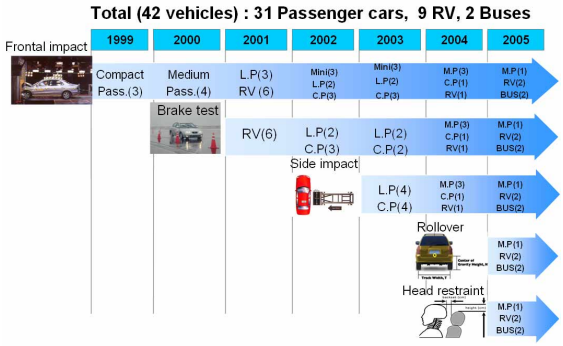
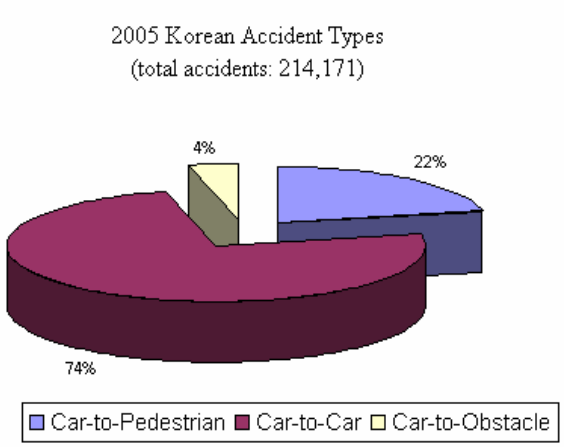


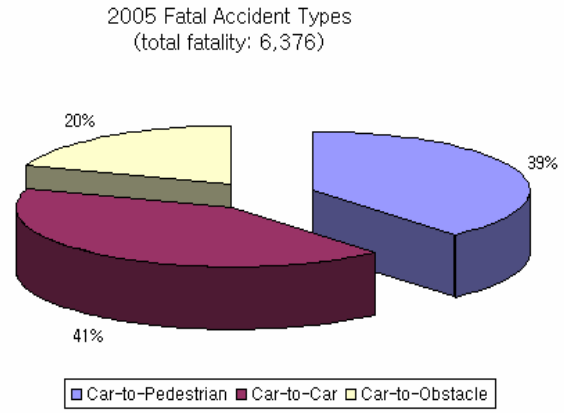
Figure 1. History and progress of KNCAP

ASSESSMENT OF SIDE CRASH ACCIDENTS

Police reported accidents data in 2005 show that 74.3% (159,063 accidents) of all accidents (214,171 accidents) were car-to-car type accidents, the pedestrian accidents were 21.8% and vehicle only involved accidents were 4.0% as shown in Figure 2. According to the police reports, during the fiscal year of 2005, total fatality of car-to-car type accidents was 2,659. Among the car-to-car type accidents fatality, the most serious accident type was side collisions. The side impact type accident's death was 717 (28 %). The following higher fatality

was rear collision (25%) and the frontal collision type was about 22% as shown in Figure 3.





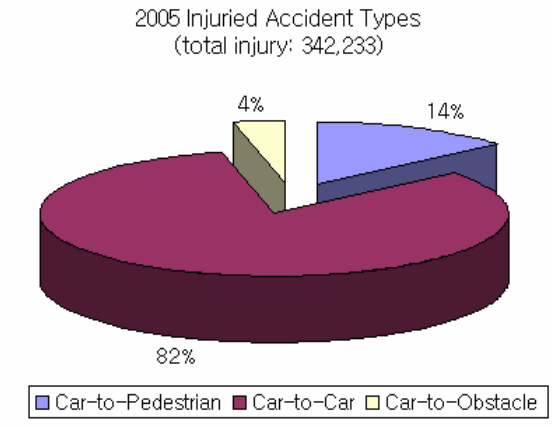
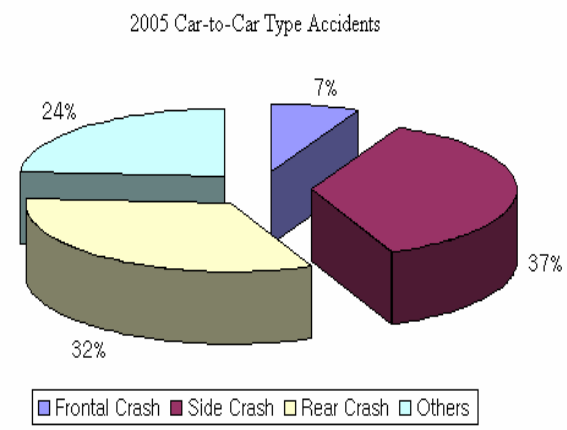
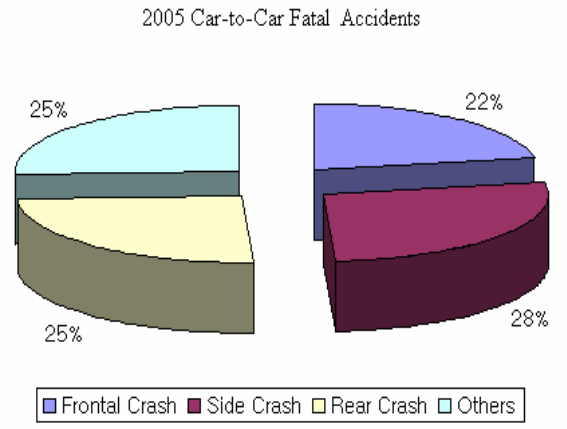


Figure 2. Traffic accidents, fatality and injury in 2005





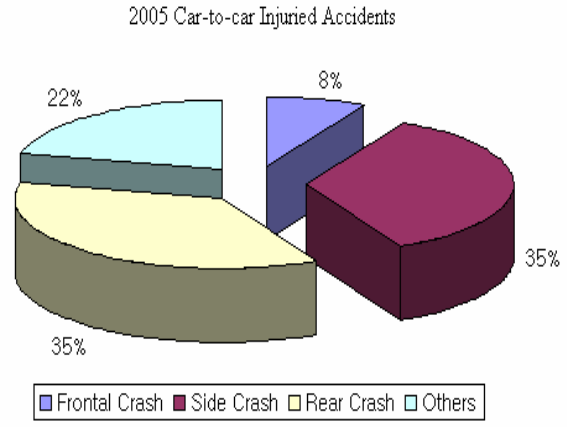


Figure 3. Car-to-Car involved accidents, fatality and injury in 2005

As shown above, the side collision was the most frequent accident type and life threatening accident in domestic traffic environments with rear collisions.

KNCAP TEST AND EVALUATION METHODS

The method of the side crash tests currently conducted by KNCAP is defined and documented in the "Regulation of motor vehicle safety standards" and the detailed test procedures and methods are listed in the bylaw of the regulations.

The test method and evaluation protocol is similar to the EuroNCAP with slightly higher impact speed. As shown in Figure 1, EuroSID-I is seated in the driver side. The reason higher impact speed than EuroNCAP is that the impact speed of Korean side impact regulation is currently set to 50 kph as shown in Figure 4. Currently the moving deformable barrier speed is 55 kph in KNCAP.

Figure 4. The schematic view of KNCAP side impact test

Table 1. Comparison of KMVSS and KNCAP

	Regulation (Act. 102)	KNCAP Side Impact
Type	90◦ Side Impact	Same
Effect. Date	2003. 1.1	2003.1.1
Speed	50 km/h	55 km/h
Dummy	EuroSID-1	EuroSID-1
Rate	Pass/Fail	5 Star rating

The performance of vehicle safety is evaluated by four items, injury rate, possibility of door opening during the test and door opening ability of after test, and leaking of fuel. The injury rate is calculated by the performance of driver side EuroSID-1. The injuries of head, chest, abdomen and pelvis will be calculated by formulation as shown in Table 2. Each point of injury can interpolate and the total maximum possible points are 12 points.

Table 2. Side KNCAP injury evaluation methods

	Injury	Criteria	Points	% AIS>3
Head	HPC	650 - 1000	0 - 4	5 - 20
Chest	Rib def, mm	22 - 42	0 - 4	5 – 30
	V*C, m/s	0.32-1.0		5 – 50
Abdomen	Force, kN	1.0-2.5	0 - 2	Abdomen rupture (0)
Pelvis	Pubic Symphysis Force, kN	3.0-6.0	0 - 2	Abdomen rupture (0)
Total			0 -12	5 - 50

The safety levels can be divided by 5 steps and the highest level has 5 stars and lowest level of side impact safety can get only 1 star as shown in Table 3.

Table 3. KNCAP star rating system

Star rating	point
★★★★★	10.50 – 12.00
★★★★	9.00 – 10.49
★★★	7.50 – 8.99
★★	6.00 – 7.49
★	0.00 – 5.99

KNCAP RESULTS AND DISCUSSIONS

During the last four years (2003 – 2006), total 21 vehicles were tested. Since small numbers of new vehicles were introduced in the market every year, KNCAP committee decided to selection of test vehicle with same class category as well as consideration of vehicle sales volume. Until recently the Korean new car sales have been dominated by large vehicle that including recreation vehicle (RV) - SUV and Van type cars, mediums size passenger cars as shown in Table 4. The KNCAP uses vehicle categories that align closely with the Code of Korean Vehicle Classifications (CKVC). The RV categories vehicle (SUV and Van) segments are combined in the KNCAP either Medium or Large depended on the engine sizes and vehicle weights.

Table 4. Sales Volume of Korean new car market

	2003	2004	2005	2006
Sub-compact	741 (-0.7)	753 (+1.5)	759 (-0.9)	759 (-0.3)
Compact	3,040 (-5.6)	2,816 (-8.0)	2,630 (-7.1)	2,441 (-7.7)
Medium	4,739 (+9.2)	5,064 (+6.2)	5,493 (+7.8)	5,907 (+7.0)
Large (incl. SUV)	1,750 (_22.3)	1,988 (+12.0)	2,240 (+11.2)	2,502 (+10.5)

Unit: 1,000 vehicles,
( ): % of increment or decrement.

Table 5. Total Number of KNCAP side impact tested vehicles

	2003	2004	2005	2006
Compact	8	-	1	1
Medium	-	3	1	2
Large (incl. SUV)	-	1	4	-

Based on the test results listed in Table 6 - 8, the most dominant factor for good star rating was the rib deflections of EuroSID-I. The next main factors were abdominal forces and pubic symphysis forces. The least influencing factors were viscous criteria and head injury criteria. All tested vehicle have full 4 points in HPC criteria thus the head injury criteria does not influence the overall star rating. In 2005, all tested vehicle have 5 stars due to their higher seating reference point, H-point, over 700 mm. Since the impact point between the moving barrier and vehicle side structures are below the H-points, the influences in chest and abdomen injuries was negligible.

Table 6. Test results and star ratings for compact cars

Year of Test	Maker	Vehicle	Grade
2003	KIA	RIO-SF	★★★
	GM-DAWOO	KALOS	★★
	HYNDAI	NEW-VERNA	★★★★
	HYNDAI	CLICK	★★★
	RENAULT- SAMSUNG	SM3	★★★
	GM DAWOO	LACETTI	★★
	HYNDAI	NEW-AVANTE XD	★★★★
	HYNDAI	LAVITA	★★★★★
2004	KIA	CERATO	★★★★
2005	KIA	PRIDE	★★★

Table 7. Test results and star ratings for the medium cars

Year of Test	Maker	Vehicle	Grade
2004	KIA	OPTIMA REGAL	★★
	GM-DAWOO	MAGNUS	★★★
	HYNDAI	NF-SONATA	★★★★★
2005	RENAULT- SAMSUNG	SM5	★★★★

2006	RENAULT- SAMSUNG	SM5	★★★★★
	GM-DAWOO	GENTRA	★★★

Table 8. Test results and star ratings for the SUVs and Vans

Year of Test	Maker	Vehicle	Grade
2004	KIA	X-TREK	★★★
2005	KIA	SPORTAGE	★★★★★
	HYNDAI	TUCSON	★★★★★
	HYNDAI	STAREX	★★★★★
	SSANGYONG	RODIUS	★★★★★

The rib deflections and abdomen forces for each test vehicles were shown in Figure 5 through Figure 7. As shown in Figures, if the rib deflections were less than 30mm or the abdomen forces were less than 1.0kN, most of all tested vehicles have at least 4 stars. To get the 5 stars, the rib deflections should be less than 25mm and the abdomen forces are less than 2.0kN.

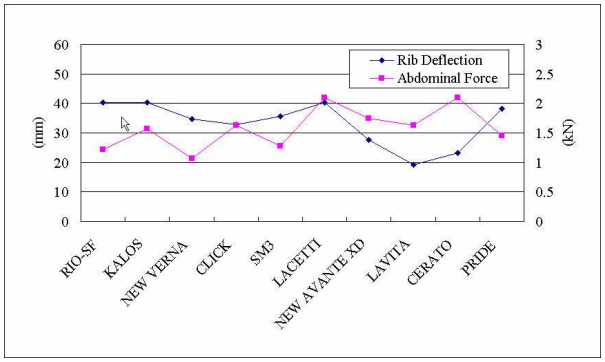


Figure 5. Rib deflection and abdominal force for the compact cars

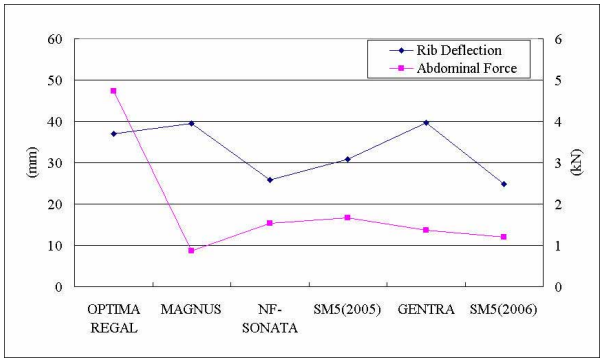


Figure 6. Rib deflection and abdominal force for the medium cars

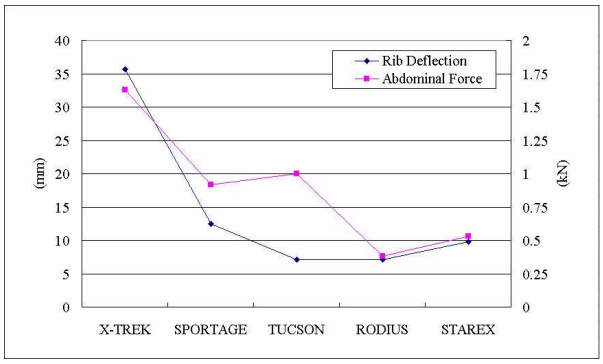


Figure 7. Rib deflection and abdominal force for the SUVs and Vans

As shown below Figures, the vehicle deformation, of course, differs greatly depending on the penetration speed at the door of the struck vehicle, and produces significant differences in the responses of the dummies. The amount of structural deformation of struck side directly influences the injury of rib deformation. To improve side crash safety performances, stiffer door impact beams or reinforced B-pillar structures are adopted recent model year vehicles. As alternative methods, additional proper padding material between door and occupant can protect the occupants. Even though there are no vehicles equipped with side thorax airbag or curtain airbag in domestically manufactured vehicles in the market. But from NHTSA study [ ], specifically side air bags systems appear to have improved side impact protection. Using a simple comparison of star ratings in the US side New Car Assessment Program (NCAP),

recent model year passenger cars and LTVs equipped with thorax air bags provided better overall thoracic and pelvic protection than vehicles not equipped. The vehicles equipped with thorax air bags may have other structural enhancements that contributed to their improved safety performance.

Figures in below show that the relationships between rib deflections and structural intrusions of the struck side door at the level of armrest.

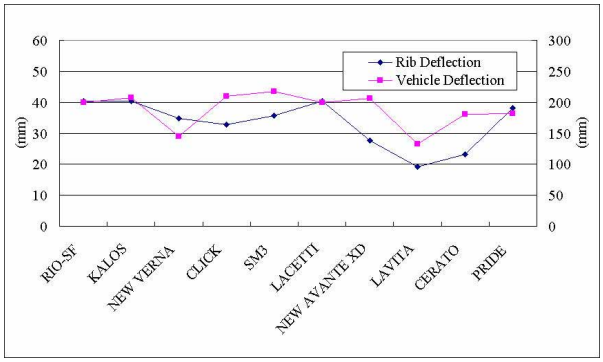


Figure 8. Rib deflection and vehicle deflection at the arm rest for the compact cars.

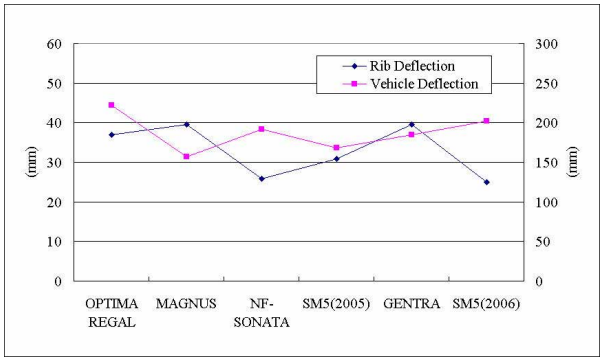


Figure 9. Rib deflection and vehicle deflection at the arm rest for the medium cars.

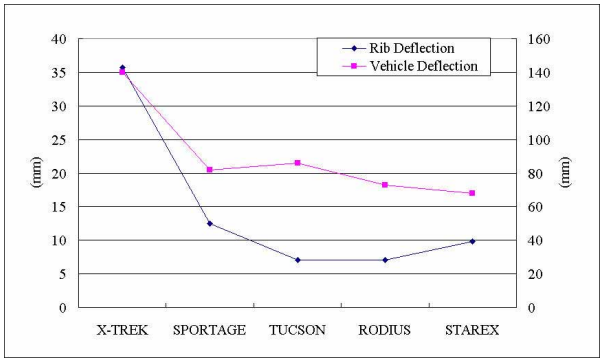


Figure 10. Rib deflection and vehicle deflection at the arm rest for the SUVs and Vans.

A correlation was found between door intrusion velocities and chest deflections. The abdominal and pelvis forces become high as the vehicle deformation at the height of SRP is larger. The amount of rib deflections were in proportion to the amount of side structural deformations. The less deformation of side structures improves the chest injury. In addition to the vehicle deformation and intrusion velocity, padding and side airbag can also affect injury criteria in a side impact.

CURRENT PROBLEMS AND FUTURE KNCAP PROGRMS

From this study, the performances of Korean side impact NCAP system was evaluated with 21 tested vehicles. Even though the evaluation periods was only 4 years test data with the limited test vehicles, this system can promote to improve safety performances in side collisions.

The most influencing factor for better star rating is rib deflection injury criteria. The most of vehicles that achieve the more than 4 stars reveal that their occupant rib deflection were less than 30 mm. If the rib deflection was less than 25mm, it can be a five star rated vehicle. Also, the abdomen force is relatively larger factor effecting in safety rating due to more than 2.0kN force of abdomen receiving a cut in marks. The HPC is the least influencing factor in safety evaluation.

In side impact tests, the injury criteria have been decreased by the side stiffness, B pillar layout, door pad, and airbag. As a result, the side impact score have improved, and the HPC, chest deflection, and pelvis force showed nearly full scores. The scores in the side impact test have become better as the ground height of the seat reference point has become greater, e.g., the MPV due to the height relation between the MDB barrier face and the seat reference point. Since in MDB tests, the contact of the dummy head does not occur in most cases, the risk of head injury which has been frequently observed in real side collisions is difficult to evaluate. Some cars have a new head protection

device like a curtain airbag. Therefore, pole impact and other tests should be introduced to evaluate these kinds of devices and head injury risk.

With close examinations of other NCAP test data such as NHTSA SINCAP, IIHS side impact and EuroNCAP, the KNCAP will be evaluated and updated to present better reproducing severalty of the real accidents with adoptions of progressive type MDB and EuroSID-2 dummy.

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