

THE PROPOSED NEW KNCAP FRONTAL CRASH TEST BASED ON THE IN-DEPTH ACCIDENT DATA

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ABSTRACT

Today, new types of frontal crash test are under discussed, globally. While, on December 2015, The NHTSA finalized a new frontal oblique impact test protocol as USNCAP, EuroNCAP still considers a new mobile frontal crash test protocol on 2020 with THOR dummies.

In Korea, despite of fatality reductions, frontal collision is considered the most sever accidents due to highest fatality ratio. With SUV, compatibility and small overlap issues were recently discussed as new KNCAP program.

This paper focuses on the suitable types of frontal test protocol as a new frontal crash test method on KNCAP to evaluate compatibility issues and integrated vehicle safety technologies through the analyses of in depth accident KIDAS data. Research on benefits for new safety technologies requires significant amounts of objective data describing both occupant injury and real road accident data configurations.

Recently, as part of research project, a pilot KIDAS (Korea In-Depth Accident Study) has been started to collect the detailed accident data. In this study, a total 258 cases of the frontal collisions were identified and analyzed.

The study provides new insights to identify the patterns of the frontal collision accidents. Currently, Frontal crash tests of KNCAP represent more than 50% overlap of damaged frontal structure accidents. 108 of 258 cases were represent both small overlap and offset of frontal crash accidents which covers 42% of all frontal accidents from the KIDAS. 50 vehicles were impacted either 11 or 01 o'clock PDOF directions. From the KIDAS, 19% of all frontal impact were angled small overlap crash accidents. The majority of frontal damaged patterns were full-wrap type collisions. From the offset collisions, 33% of injury was scored MAIS 3+ severity. Updating offset test procedure will be needed to enhancement of frontal crash program of KNCAP.

INTRODUCTION

Frontal crash is still the most relevant accident in terms of injury causation [1]. While the stability of passenger compartments has been improved significantly recent years, the performance of the advanced restraint system becomes now even more important [2]. Vehicle frontal impact crashworthiness is assessed by dynamic vehicle-into-barrier crash tests. These tests have typically employed full-wrap rigid barriers, e.g., US-NCAP, KNCAP, JNCAP and C-NCAP with 56kph impact speed or 40% frontal overlap deformable barriers, e.g., IIHS, Euro NCAP, KNCAP, JNCAP, C-NCAP and other NCAPs. Since the implementation of these tests, substantial improvements in test performance have been reported. Recently, the most of domestic

tested vehicles achieving five stars in KNCAP both in full-overlap and offset frontal tests.

US-NCAP increased from less than 30% in 1979 to greater than 98% in 2007 [3]. Vehicles rated "good" by IIHS have increased from less than 50% in 1995 to 91% in 2009 [4]. Following improvements in these configurations, the small overlap impact (SOI) has emerged recently as a prominent cause of frontal crash injury and death, even with belt and airbag restraints [5]. Contrasted with large overlap impacts (LOI), SOI crashes are characterized by vehicle deformations which fail to engage longitudinal structures intended to absorb crash energy. These impacts have been difficult to define in existing motor

vehicle crash databases.

In the traditional restraint system test, the vehicle is crashed between 50 and 56 km/h speeds against the rigid wall independent of the vehicle mass. This test procedure used in many countries all over the world. In real-world car-to-car impacts a light vehicle is more likely to be hit by a heavier vehicle and due to the principle of conservation of momentum, the lighter of the two vehicles has to withstand higher loading than the heavier vehicle. Higher loading not only affects passenger compartment structural integrity, but also vehicle body acceleration as the lighter of the opponents suffer from a greater change of velocity (Δv) due to the conservation of momentum. A test with a frontal mobile barrier would reflect these circumstances and was discussed several times in the past [6], [7] and [8]. In Europe, the accident studies reveal that many injuries are caused by high vehicle acceleration in frontal impacts compared to injuries caused by intrusions into the passenger compartment [2]. It was also stated that the accidents with acceleration loading induced injuries had a high overlap. The crash tests with a high overlap seem to have a higher priority in Europe [15].

However, in US, the crash tests with a small overlap at the corner of the vehicle has been conducted in both NHTSA and IIHS as parts of NCAP programs [6, 12–14].

KNCAP FRONTAL IMPACT PERFORMANCES

As stated in the previous page, KNCAP has two different frontal impact tests. First, introduced in 1998, the full wrap frontal impact test was performed at the velocity of 56 km/h with two H3 50%tile dummies. In 2014, the passenger seated dummy was changed to 5%tile female H3.

From 2017, driver seated dummy will also be changed to 5%tile female dummy to protect female driver. The performance of the vehicle safety is evaluated by the injury rate, possibility of the door opening during the test, the door opening ability after the test and the fuel leakage. The vehicle performance is evaluated with 5 star rating system with maximum 16 points.

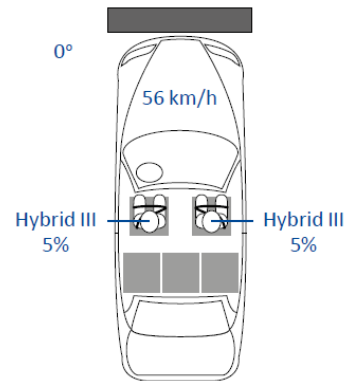


Figure 1. KNCAP full-wrap frontal test configuration

In 2009, the offset frontal impact test was adopted to reducing real-road fatality with 64 km/h impact speed toward to 40% overlapped deformable barrier with two 50%tile H3 dummies.

In 2017, the test protocol will be updated with Q series child dummies (Q6 and Q10) that were seated rear seats. The evaluation is similar to full-wrap test except injury criteria for male and child dummies.

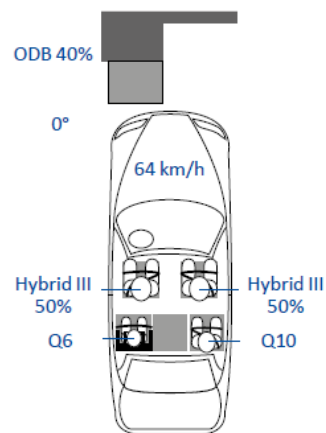


Figure 2. KNCAP 40% offset frontal test configuration

The following table (Table 1) show that recent years vehicle safety performances. In KNCAP, each individual test is rated 5 star rating system with points. Then the overall rating of vehicle safety is calculated based on the passive safety and active safety scores. The weighting factor for the passive safety (frontal, side, pedestrian) is 60%.

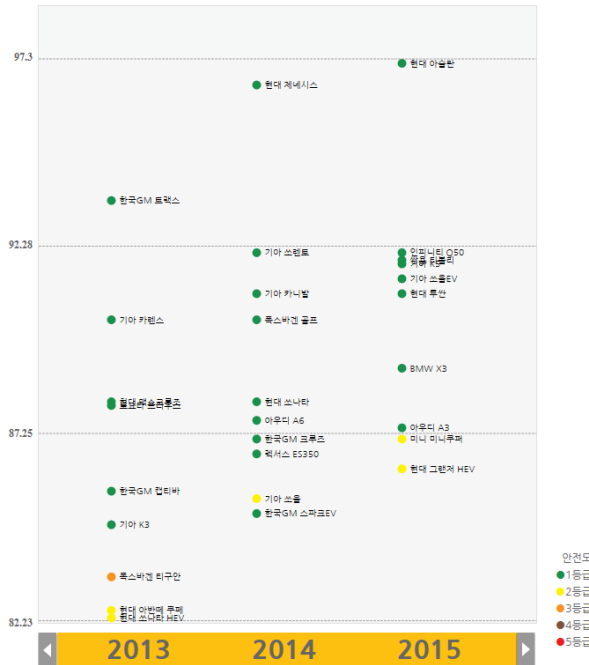


Figure 3. KNCAP overall safety performances

MACROSCOPIC POLICE ACCIDENT DATA

Despite of a numerous efforts of enhancement of vehicle safety performances both regulatory bodies and industries, there is still accidents and fatality on the road. From police car-to-car accident classification, there are 4 different collision categories with unknown type. They categorized only head-on, 90 degrees side impact, moving vehicle rear-end collision and stationed vehicle rear-end collision types. According to police classification of accident types, for example, at the crossroad, while vehicle 1 is traveling it's forward driving direction, vehicle 2 may appear from corner. If accident cannot avoid, vehicle 1 can be defined "side impacted vehicle" and vehicle 2 is "front impact vehicle". But, in police classification, it is an accident defined as side impact accident. All fatalities and injuries involved in this accident was counted as side impact victims.

From 2012-2015 police accident data, fatalities and injuries from vehicle to vehicle accidents were 7,937 and 1,099,775 respectively. The ratio of fatalities and injury from side collisions were 32% and 37%, respectively. Vehicle to vehicle frontal collision type fatalities were only 1,223 during the 4 year periods and the portion was 15.4%. Injuries ratio from frontal

collision was 5.7%.

Table 1. 2012-2015 National police data

Accident Type	Collision Type	Year	2012	2013	2014	2015	2012-2015	Car-Car %	Total %
Car-Car	Head-on Collision	Accident #	7,174	6,370	5,840	14,488	33,872	5.2	3.8
		Fatality #	329	380	259	355	1,223	15.4	6.3
	Side Collision	Injured #	13,722	12,118	11,087	25,614	62,541	5.7	4.6
		Accident #	68,131	60,806	56,935	65,498	251,370	38.7	28.1
	Moving Vehicle Rear Collision	Fatality #	779	592	555	604	2,530	31.9	12.7
		Injured #	112,437	99,847	92,300	104,991	409,575	37.2	30.1
	Stationed Vehicle Rear Collision	Accident #	26,841	24,381	24,783	28,349	104,354	16.1	11.7
		Fatality #	358	341	309	354	1,362	17.2	6.9
	Others	Injured #	50,078	45,829	45,760	52,070	193,737	17.6	14.2
		Accident #	21,727	18,824	18,245	18,808	77,604	12.0	8.7
	Others	Fatality #	225	195	195	191	817	10.3	4.1
		Injured #	43,011	37,194	35,650	36,502	152,357	13.9	11.2
Others	Accident #	38,582	44,915	56,378	42,328	182,203	28.1	20.4	
	Fatality #	455	525	596	429	2,005	25.3	10.1	
Others	Injured #	59,603	69,807	87,350	64,805	281,565	25.6	20.7	

When road construction authority or traffic management agency planed solve the road traffic situations, there may be some advantages using police classification of accident. However, for vehicle safety enhancement views, it is very difficult classify the issues of safety systems as well as mechanics of injuries.

ANALYSIS OF FRONATL COLLISIONS IN KIDAS

An objective of this study was to examine collision and injury patterns of frontal crashed based on KIDAS data. From the results of current works, it is intension to the further consideration of KNCAP roadmap to protect from frontal collisions.

As part of research project, KIDAS (Korea In-Depth Accident Study) has been started to collect the detailed accident data. From three different regional areas, in-depth accident data has been collected since 2012.

In this study, a total 251 cases of the frontal collisions were identified and analyzed based on the data collect from 2014 to 2016. Collected cases were classified SAE J224 Collision Deformation Classification (CDC) codes (Figure 4).

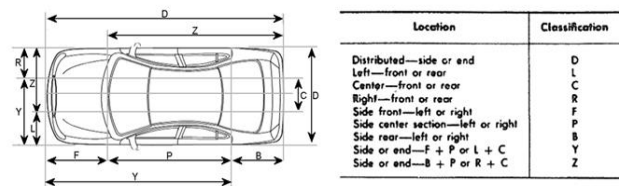


Figure 4. CDC code column 4 for horizontal damage codes for frontal crashes

From KIDAS (2014 - 2016), the total 419 cases of accident can be divided by frontal, side, rollover and rear-end collision types classified by vehicle's damage CDC code. As shown in Figure 5, the frontal collision is the most frequent type of accident. The portion of frontal collision was 64% of all collected accidents except pedestrian involved accidents.

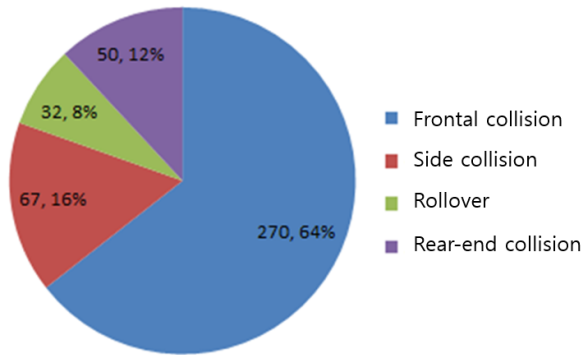


Figure 5. Distributions of collision types in KIDAS (2014-2016)

From 270 cases, 12 cases were excluded due to missing information, such as vehicle information, injury severity, and injured body part etc. Therefore, the total 258 cases were examined as frontal collisions type accidents. The frontal collision was defined by 11 o'clock, 12 o'clock and 01 o'clock direction on the PDOF from 1st column of CDC code.

The damage patterns of frontal structures were classified by 4th column of CDC code. The small overlap (less than 40% of frontal structure damaged in horizontal direction) was extracted from 11 o'clock or 01 o'clock PDOF with L or R code on CDC code (4th column).

The full-wrap frontal collision was defined when PDOF was 12 o'clock with D code. The offset collision was defined with 11 o'clock, 12 o'clock or 01 o'clock with Y or Z code. The small overlap cases were 50 cases (01 o'clock 13 cases, 11 o'clock 37 cases). The full-wrap collision was 150 cases and the offset collision was 58 cases as shown in Figure 6.

From analysis of injured occupants, information of 190 patients was acceptable from 258 cases of frontal collision accidents. Each accident was analyzed with the injury severity and patient's physical conditions to compare the severity of the accident based on delta v

with variables of age, gender, weight and height of the patient.

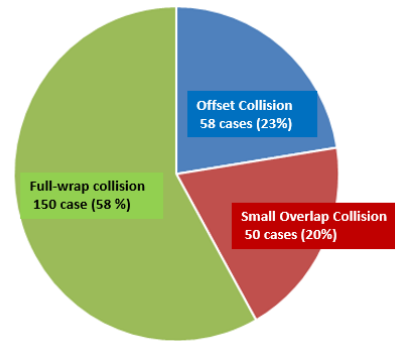


Figure 6. Distributions of Frontal collision types in KIDAS (2014-2016)

The average delta v was 22.12km/h and the average injury severity (MAIS) was 1.93. Among 3 different types of frontal collisions, the offset type frontal collision experienced the highest delta v (31.45km/h). Since offset case was the higher delta v, the injury severity was also higher than two other types of collisions. In the offset collision case, the average score of MAIS was 2.07. For the small overlap case, there was no significant meaning in both delta v and injury severity.

Table 2. Comparisons of average Delta V and MAIS in frontal collisions (KIDAS)

	Average	Small overlap	Offset Collision	Full-wrap Collision
Delta-v	22.12km/h	23km/h	31.45km/h	31km/h
MAIS	1.93	1.82	2.07	2.00

As shown in Table 3, the injured body part and severity were compared with different frontal collision types. Compared with overall average injury severity, the injury of spine and upper extremities were higher than average AIS scores when occupants involved small overlap type accidents. Especially, the spine injury score (average AIS 2.83) was oddly higher than other crash types. There was no evidence of sever head or lower extremities injury due to angled frontal impact. This shows that there was no indication of fail of

contact to deployed airbag or a large intrusion of compartment. While IIHS's assessment for small overlap protocol focuses injury of head, neck, chest, hip, thigh and lower extremities, however, there are no significant indications of these severities.

Table 3. Comparisons of injured body and severity in frontal collisions (KIDAS)

	Average	small overlap	Offset	Full-wrap
AIS 1 (head w/o face)	1.70	1.59	1.57	1.82
AIS 2 (face)	1.32	1.16	1.25	1.40
AIS 3 (neck w/o spine)	1.25	1.11	1.31	1.25
AIS 4 (thorax w/o shoulder)	1.91	1.80	1.86	1.93
AIS 5 (abdomen)	1.75	1.56	1.86	1.79
AIS 6 (spine)	2.30	2.83	1.5	2.25
AIS 7 (upper extremities)	1.46	1.55	1.39	1.33
AIS 8 (lower extremities)	1.59	1.52	1.64	1.51
AIS 9 (not specified)	3.15	1.50	n/a	2.5

In KIDAS, the physical body size of average of injured patients during the frontal collisions was less than the size of 50%tile H3 dummy. For the small overlap accident cases, the average victim's age was 40 years old with 168 cm standing height, and 69 kg body weight. This smaller size than western standard may influenced injury patterns during the frontal crash accidents.

Table 4. Physical size of patients in frontal collisions (KIDAS)

	Average	small overlap	Offset collision	Full-wrap Collision
Age (yo)	43.37	40.41	45.9	44.54
Height (cm)	162.24	168.2	160.8	160.17
Weight (kg)	65.10	68.89	58.88	64.20

The maximum severity of injured patients in KIDAS was shown in Table 5. The average MAIS 3+ severity from frontal collisions was 24.8%, while the small overlap type was similar to the average MAIS 3+ score. However, the offset and full-wrap type frontal collisions were much higher than the average scores. Two types of cases, the severity of MAIS 3+ was 33%. This indicates that when these two types of accidents

occurs, the probability of severely injury is about 1/3.

Table 5. Comparisons of MAIS +3 caused by three different types of frontal accidents in KIDAS

	average	small overlap	Offset collision	Full-wrap collision
MAIS 3+ (%)	24.80%	25%	33.33%	32.89%

CONCLUSIONS

In this study, three different types of frontal collisions were classified as small overlap, offset and full-wrap frontal crash accidents. KIDAS couldn't represent national accident scenario due to no detailed classification of police accidents.

The limitation of this study is only based on the collection of accident data from three different local areas, which represent a typical mid-size city with having highways, main national roads and regional roads with city roads.

1. From KIDAS, unlike police data, the frontal collisions is majority types of vehicle accident. In terms of vehicle occupants, more than 64% of accidents were involved crashed frontal structural of vehicles excluding pedestrian accidents.
2. Among these frontal collisions, the portion of full-wrap type accidents represents more than 50% of all frontal collisions. The offset type shows 23% and 20% for small overlap type frontal collisions.
3. There was no evidence of severe head and lower extremities injury during the small overlap collisions. In addition, the severity of injury was not higher than overall average of frontal collisions. The most severely injured patients was from either offset or full-wrap type accidents.
4. In terms of probability of MAIS 3+ severity, the offset type accidents is one of candidate of enhancing frontal crash programs.

From this study, it is recommended to further investigation of frontal collision to update the current

KNCAP frontal crash programs. In order to global acceptance or harmonization of KNCAP protocol, it is needed to further communications with other NCAP agencies.

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