Submitted by the expert from Republic of Korea

Informal document GRSP-73-38
(73rd GRSP, 15-19 May 2023
agenda item 3)

Post-crash Safety of Hydrogen HDV

Submitted by the expert from Republic of Korea

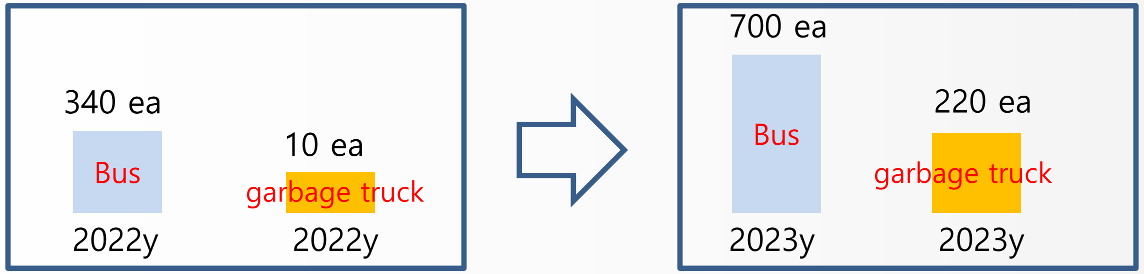
- Research result -

Korea Transportation Safety Authority
Korea Automobile Testing & Research Institute

Supply plans for heavy duty vehicle in Korea

Continuously expand HDV (commercial vehicle) share

- '22: bus 340 ea, garbage truck 10 ea ➔ '23: bus 700 ea, garbage truck 220 ea



Accumulated sales goal of HDV (commercial vehicle) based on Korea Hydrogen Mobility Supply Plans

- 2025y: 5000 ea ➔ 2030y: 30,000 ea

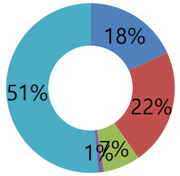
Background

Representative HDV (bus) accidents in Korea

* Accident Statistics: 1,408 accident data (2018-2019) from the biggest transportation company and 720,000 accident data (2021) from Traffic Accident Analysis System (TAAS) in Korea.

Various crash cases of HDV

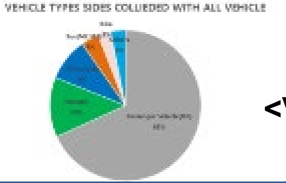
- Side impact crash cases take the biggest portion.



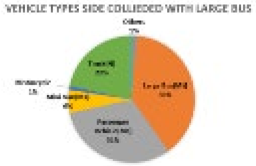
<Crash types of large bus in Korea>

- Rear-end : 18%
- Side Collision : 22%
- Frontal Crash : 7%
- rollover : 1%
- Solo Crash : 51%

- Large buses are more likely to crash with HDV (large bus and truck) compared to other vehicles in side collision accidents.

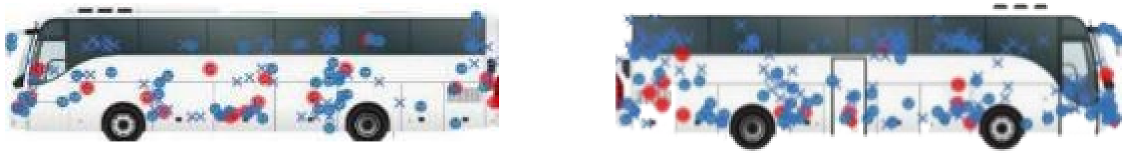


<Vehicles types involved in crash accidents>



Accident statistics of side collisions

- Side impacts take place at broad range of lateral side of HDV



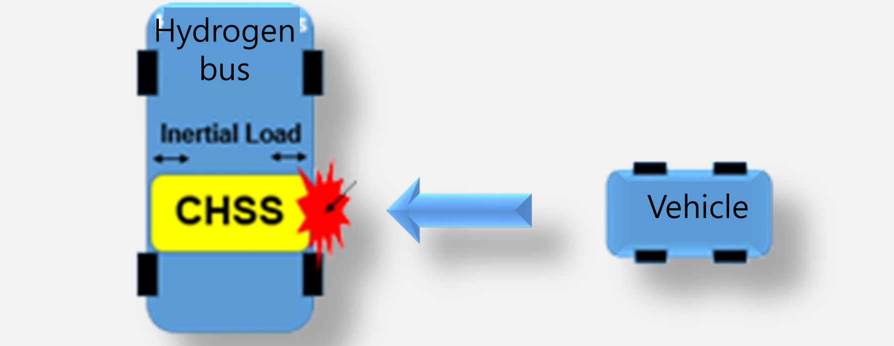
<Impact points of bus side> ※ Red: severe, Blue: minor

- Collision velocity → HDV (Bus)-to-LDV: 40-60 km/h, HDV (Bus)-to-HDV (Bus): 15-40km/h

Background (necessity for new test methods)

The fuel integrity risk of passenger car can be assessed by both inertial load and impact load during collision test such as the UN R 94, 95 and 135.

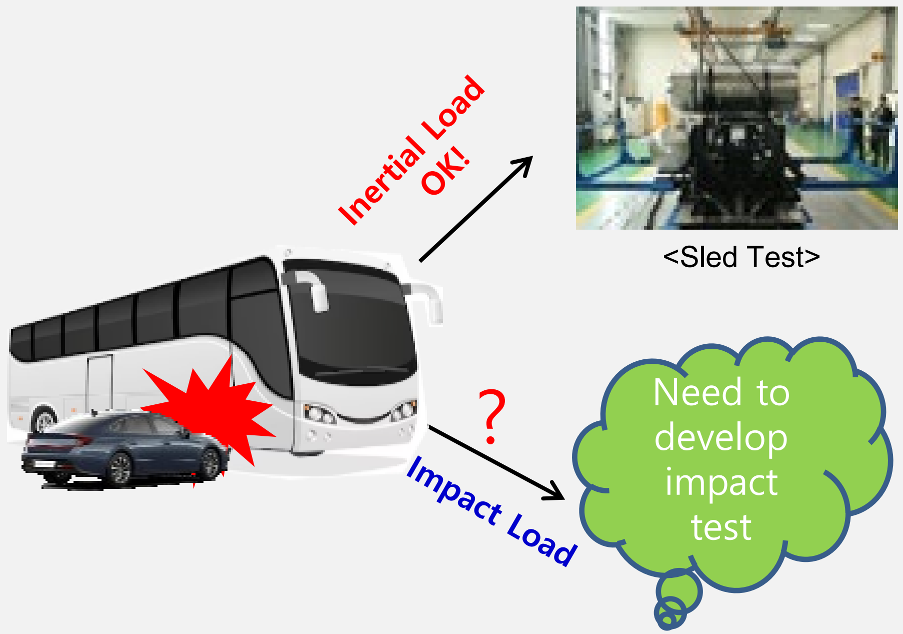
- Inertial load from the movements of CHSS
- Impact load from the contact between CHSS and intruded structures / barrier



<The risk factors of CHSS(Fuel system) during crash>

Heavy-Duty Vehicles (HDV) are assessed by conducting the full scale crash test only.
Furthermore, those vehicles are not subject to post-crash safety under UN GTR No. 13.

- Thus, fuel integrity risk from the inertial load can be assessed through a sled test.
- However, the evaluation of fuel integrity risk from the impact load has not been established yet.



Research results

Research overview

Objective

- 1st Step ('20-'21): Confirm the severity of fuel system in various side collisions.
- 2nd Step ('22-'23): Develop a new evaluation method of fuel integrity safety reflecting crash mechanisms.

Test concepts

- 1st Step: full scale crash test reflecting various side crash situations.

<Roll-over test>

<30km/h HDV-HDV side crash test>

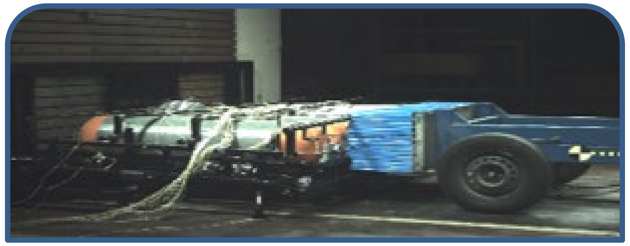
<50km/h HDV-950kg MDB side crash test>

<50km/h HDV-1100kg MRB side crash test>

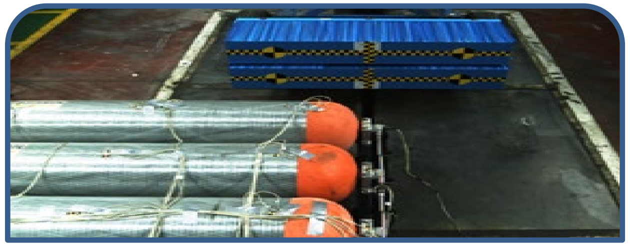
<54km/h 27° HDV-1100kg MRB side crash test>

- 2nd Step: CHSS module test to ensure fuel integrity/safety during side collision.

<CHSS module test with protective structure>



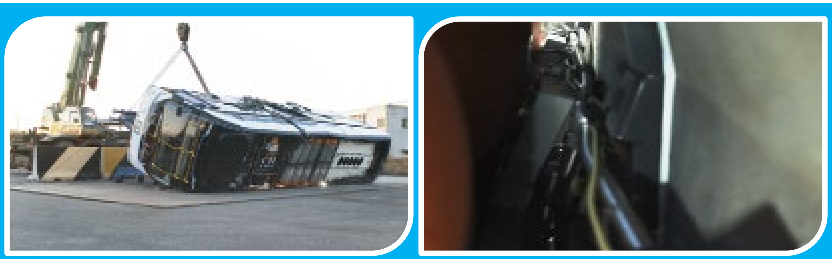
<CHSS module test in longitudinal direction >



<CHSS module test in offset lateral direction >

Research results

Conclusion of full scale crash test


[Roll-over Test]


[30km/h HDV-HDV side crash test]

High fuel system severity according to direct impact load on side collision


[50km/h HDV-1100kg MRB side crash test]


[50km/h HDV-950kg MDB side crash test]


[54km/h 27° HDV-1368kg MDB side crash test]

Conclusion of full scale crash test

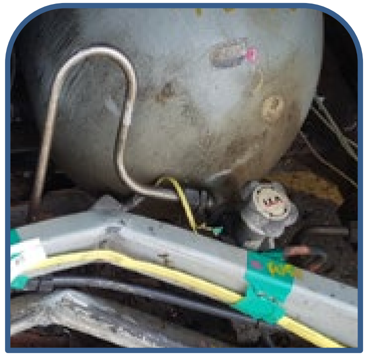
1. The risk of fuel system such as hydrogen fuel leakage due to the fuel system breakage in full vehicle crash

- Hydrogen gas leaked due to fracture of fuel system (valve or fuel connection line) in 3 side impact cases.
- There is a need of new test methods reflecting the direct impact to fuel systems in crash.

<Various crash test results>

	Roll-over	30km/h HDV-to-HDV	50km/h 950kg MDB	50km/h HDV-to-1100kg MRB	54km/h 27º HDV-to-1368kg/h MDB
Contact of Fuel Systems	0	0	0	0	0
Breakage of Fuel system	X	0 (Fracture of Fuel 2^{nd} valves)	X	0 (Fracture of Fuel 5^{th} valves)	0 (Fracture of Fuel line in 5th valves)
Fuel Leakage	X	0	X	0	0
Attachment of Fuel tanks	0	0	0	0	0


<Fracture of fuel valve>


<Disconnected fuel line>

2. The current requirement (“the attachment of fuel system”), which is an acceleration based test method (sled test) is not enough to secure the post-crash safety

- In particular, all side impact test results meet the requirement of UN R 134 sled test, but hydrogen leaked.
- Sled test requirement specified regarding the post-crash fuel system integrity in UN R 134
  - The requirement of Sled test applied to HDV regarding to post-crash Fuel system integrity
  [**7. 2. 3. Container Displacement – The Storage container(s) shall remain attached to the vehicle at a minimum of one attachment point**.]

Research results

The reasons for the need of full scale crash test

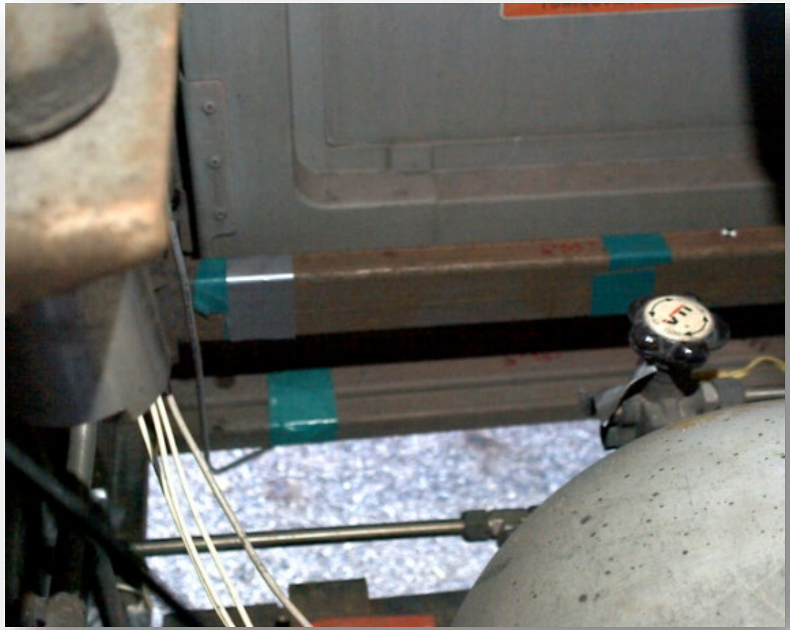
Availability of evaluation methods

Sled test can not assess fully post-crash fuel system integrity of HDV.

» **Direct impact test is necessary** for evaluating the effect of breakage of fuel system due to actual crash severity.

Can the sled test assess the post-crash fuel system integrity?

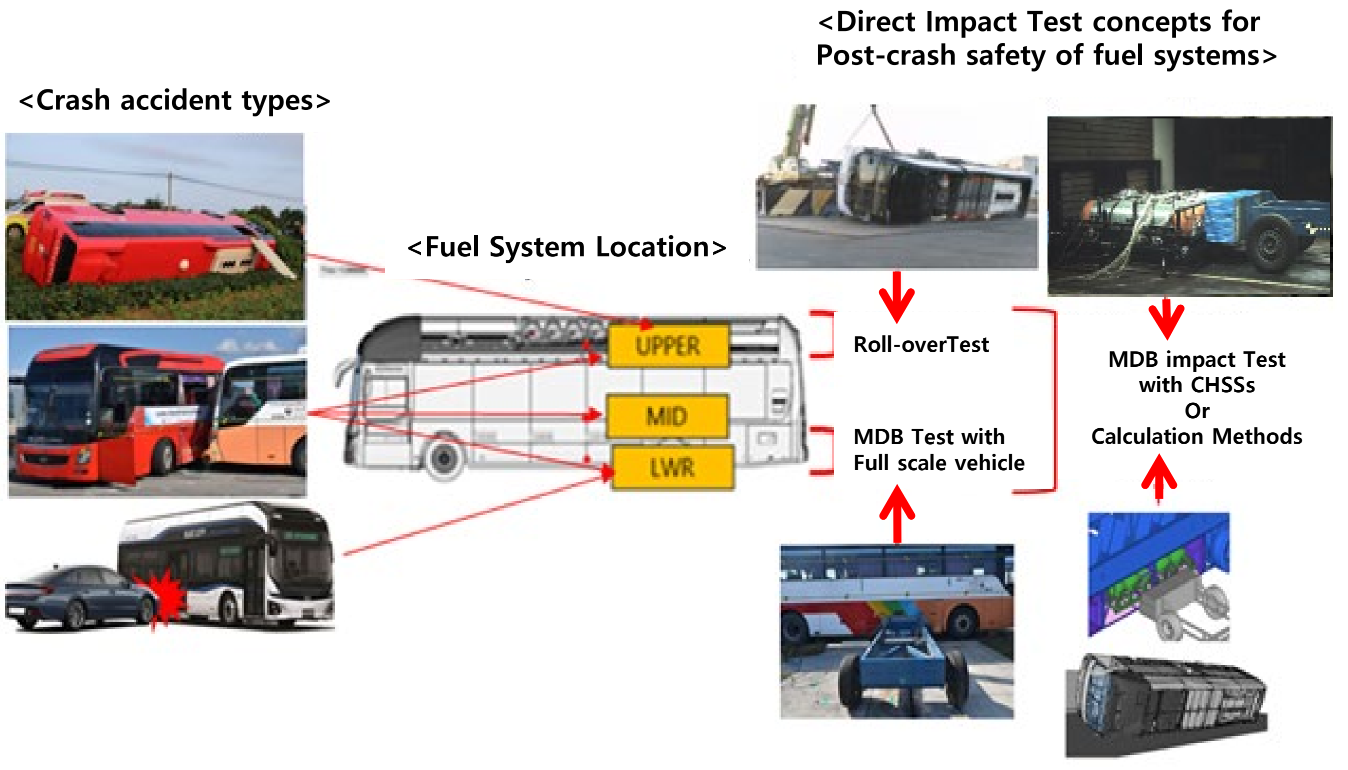
<Sled test based on crash acceleration>



<Actual crash situation>

Research results

Concepts of CHSS module impact test



<HDVs with CHSS installed over 800 mm from the ground >

CHSS Locations of HDV	Optimum Test methods	Remarks
Upper Section	Roll-over test	Similar to UN R 60 (Roll-over test)
Lower Section below 800mm	MDB Impact Test to whole vehicle	Similar to UN R 95 (Roll-over test)
Whole vehicle section	MDB Impact Test to CHSS Modules	

<Optimum crash test modes according to CHSS locations of HDV for fuel system safety>

Research results

Approach_1 to CHSS module impact test

Evaluation methods of similar regimes about CHSS module impact test

<Sled test on CHSS or REESS modules of HDV>

Requirement OK

<Suitable for CHSS/REESS modules>

Important point

acceleration of sled test is not actual crash test data of the vehicle with CHSS approved but common-law data under UN R 134 or R 100. (ex: 5g in case of M3/N3)

Accelerations for vehicles of categories M_3 and N_3:

(a) 6.6 g in the direction of travel (forward and rearward direction);

(b) 5 g horizontally perpendicular to the direction of travel (to left and right).

<Crush test on REESS>

Requirement OK

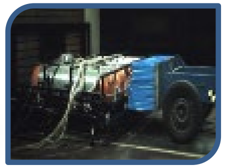
<Suitable for REESS modules>

Important point

Force of collision test is not actual crash test data of the vehicle with REESS approved but common-law data under UN R 100 (ex: 100 KN)

Proposal concepts : Simplified test method for CHSS module(Components)

<CHSS modules of HDV>



<CHSS module impact test>

<Suitable for any CHSS modules>

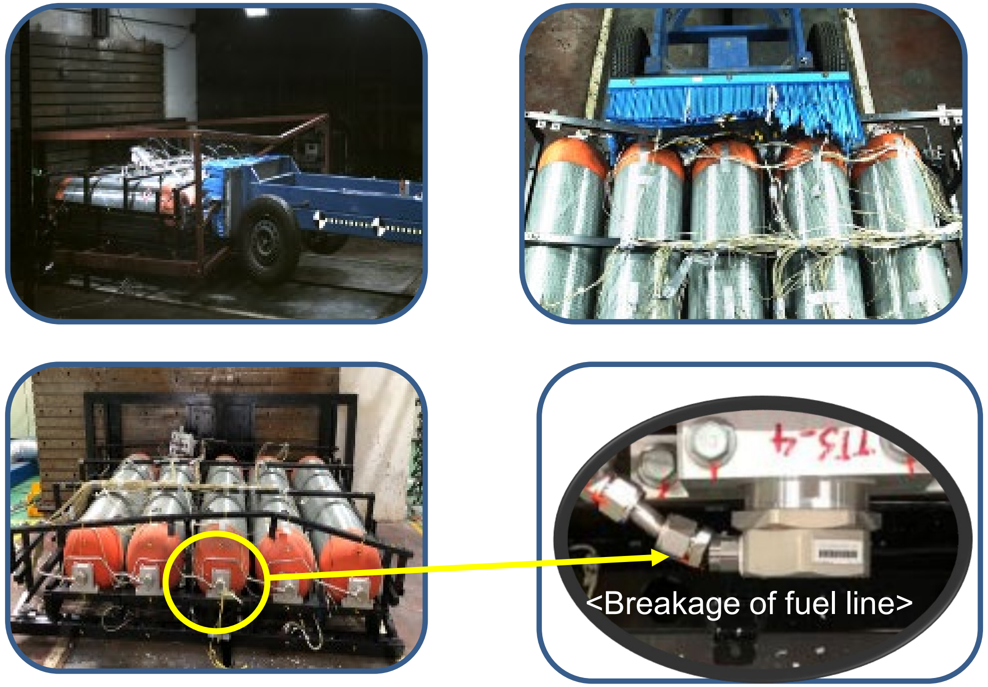
The CHSS modules in CHSS module impact test is suitable for any CHSS placements of HDV

Result of CHSS module impact test according protective structure

In the case of with the protective structure
No breakage of fuel system

<50km/h CHSS module impact test (w/ P) in longitudinal direction (LTD)>

In the case of without the protective structure
Breakage of fuel system



<50km/h CHSS module impact test (w/o P) in longitudinal direction (LTD)>

Research results

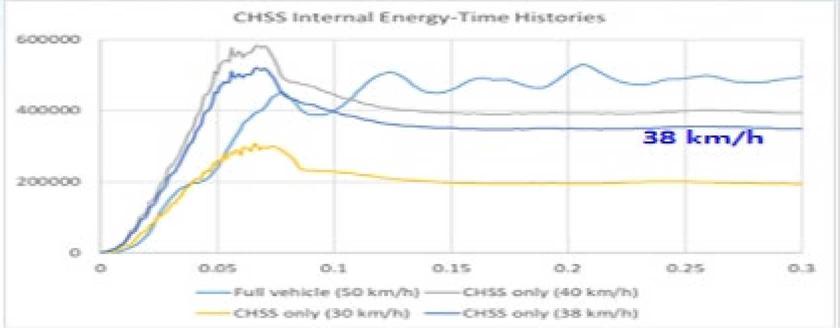
Approach_2 to CHSS module impact test

Optimum Impact velocity for CHSS module test w/o P

40km/h CHSS module (w/o P) impact test may be the optimum test method.

- Protective structure guards the fuel system from strong impact.
- Protective structures surrounding CHSS module are various according to vehicle types.
- New test can represent the post-crash safety regardless of protective structures surrounding CHSS module for test simplicity and ease of test.
- According to simulation results below,40km/h CHSS module (w/o P) is a little severer than full scale crash test and simulation results (34-38km/h) of equal conditions.

*** The crash severity of 50km/h MDB in actual full scale crash tests may be lower than the 40km/h MDB upon CHSS module without protective structure**



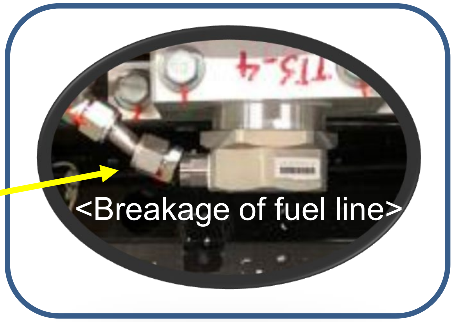
		KE	Min. KE (A)	Max. IE (B)	Structure (C)	CHSS (D)	Barrier (E)	(A+D+E)	Impact speed
Full bus (50 km/h)		92,100	4,230	87,870	45,610	530	37,500	42,260	34.0
					⇩	⇧			
MDB	50 km/h	92,200	0	47,200	0	13,900	33,300		
	40 km/h	59,100	0	31,000	0	584	30,400		
	30 km/h	33,300	0	21,500	0	307	21,200		

<Simulation results for deducing optimum impact spped under CHSS Module(w/o P) impact test>

Results of CHSS module(w/o P) impact test according to Impact speed

In the case of 50km/h impact Speed
Breakage of fuel system

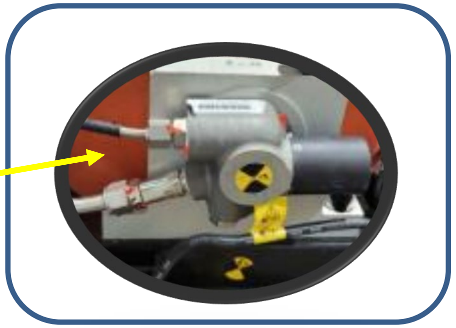


<50km/h CHSS module impact test (w/o P) in longitudinal direction (LTD)>

In the case of 40km/h impact Speed
No Breakage of fuel system



<40km/h CHSS module (w/o P) impact test in longitudinal direction (LTD)>

Summary of CHSS module impact test

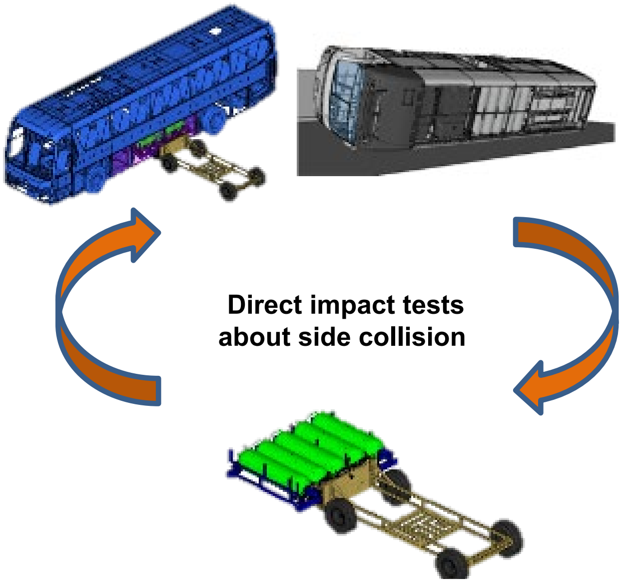
Results of CHSS Module(Component) impact test

- Direct hard impact or breakages of the fuel system contributed to fuel leakage takes place similar to full scale crash test (whole vehicle test).
  => The test results of both 50km/h CHSS module (with protective structure) impact test and 40km/h CHSS module (without protective structure) are similar with those of full scale crash test.

<Test results of fuel system safety according to various 950kg MDB test>

	50km/h MDB Test (Full scale crash test)	50km/h CHSS Module W/P Impact test in LTD	50km/h CHSS Module W/O P Impact test in LTD	40km/h CHSS Module W/O P Impact test in LTD	50km/h CHSS Module W/O P Impact test in LD
Fuel system Contact (Strong Impact)	O	O	O	O	O
Fuel system Breakage	X	X	O	X	X
Fuel system Deformation	O	O	O	O	O
Fuel Leakage	X	X	O	X	X
Attachment of Fuel tanks	X	X	X	X	O

Similar results about post-crash mechanism compared to full scale crash test



Conclusion

Conclusion

01 Current requirement cannot assess the post-crash safety of hydrogen HDV, unlike passenger vehicles (M1)
- Sled test (acceleration based test) does not reflect the fuel leakage caused to direct impact; however, most fuel leakage in collision are caused by fuel system breakage due to direct impact.

02 It is necessary to consider the various fuel system of Hydrogen HDVs
(ex: fuel system types or install location)

03 3) It is difficult to evaluate only whole vehicles due to vehicle manufacturing system, cost, etc.
=> The test methods should be simple and repeatable, considering HDV characterization.

Proposal

STEP 01. The post crash safety of hydrogen HDV fuel system should be equal to passenger vehicles (M1 or N1)

STEP 02. However, HDV is assessed only by sled test, and this is not enough to secure post-crash safety.
Therefore, a new evaluation method should be developed.

STEP 03. Furthermore, when extending the post-crash safety evaluation to include new impact tests,
it shall ensure that this new test does not limit the technology development for hydrogen fuel system of HDV.

STEP 04. It proposes to include the side impact of HDV as New items of phase 3 activity in GTR 13

Thank you

for your attention!

Korea Transportation Safety Authority
Korea Automobile Testing & Research Institute

E-mail : ijm2000@kotsa.or.kr