Research Activities of HFCV in Korea

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Contents

- Hydrogen Leakage Test
  - Driving Mode
  - Stop Mode

- Rear Impact Test
  - Possibility of Hydrogen Discharge
  - Storage Verification Test

- Summaries
Hydrogen Leakage Test: Driving Mode

- **Goal**: Verification of single failure conditions

- **Conditions**
  - Driving speed: 36 km/h
  - Open space: 14.1 m x 12 m x 6 m
  - Leaking point: fitting area between high pressure fuel line and refilling line in the rear of vehicle
    - Leaking flow: 131 NL per minute

- **Simulation Model**
  - Tool: STAR-CCM+
  - Mesh: polyhedral mesh (1,060,000)
  - Turbulence model: $\kappa-\varepsilon$ model
  - Steady-state analysis
Driving Mode Simulation Results

- **Results**
  - Hydrogen was diffused by outside air flow
  - Hydrogen concentration level over 4% by volume in air is localized near leaking area

![Vehicle underbody view](image1)

![Section A-A](image2)

![Detail of B](image3)

![Air flow outside vehicle](image4)

![Velocity profile near storages area](image5)
Stop Mode Test Conditions (1)

- Positions of hydrogen sensor

- Expected hydrogen leaking points:
  - High(5)/low(4) pressure lines and engine room(2)
Stop Mode : Test Conditions (2)

- Conditions of hydrogen leaking flow
  - 10 NL per minute : low leaking mode
  - 40 NL per minute : max. leaking mode before activation of excess flow valve
  - 131 NL per minute : leaking limit in FMVSS 301
Hydrogen Leakage Test Results

- **Driving Mode**
  - Diffused rapidly due to wind flowing outside vehicle
  - Sensors did not detect leaking hydrogen except sensors near leaking area

- **Stop Mode**
  - Leaking hydrogen may enter into vehicle through holes on the bottom if hydrogen leaks underneath the body
  - Leaking hydrogen may enter into vehicle through running HFCV system if hydrogen leaks in engine room ➔ Preventive measure needed
  - Hydrogen continued to leak for about 10 seconds before shutdown after 2% hydrogen was detected
  ➔ There were some area where hydrogen up to 4% was detected before shutdown.
  But concentration dropped below 4% within one minute

- **Conclusions**
  - Optimization of number of sensors and their locations is needed for effective detection depending on vehicle structure
  ➔ 2-3 sensors out of 5 sensors may be removed in case of HFCV SUV
  - Interior sensors should be considered for detecting hydrogen entering from outside
Rear Impact Test (Fuel System Integrity)

- Goal: Verification of fuel system integrity

- Test Vehicle
  - Mock up fuel cell vehicle

- Test Conditions
  - KMVSS article 91 (FMVSS 305): 48 km/h rear impact test
  - Filled with helium 90% of normal working pressure
  - During the crash, opened storage valve (severe condition)
  - After crash test, evaluate hydrogen discharge
Rear Impact Test Results: Hydrogen Discharge

- After impact, no hydrogen discharge
  - High pressure sensor: 30 MPa
  - Low pressure sensor: 1 MPa
Rear Impact Test Results: Verification Test of Storage

- Verification Test of Storage
  - Storage was damaged due to deformation of suspension during impact
  - Verification test of damaged storage ➔ No noticeable degradation

Under body rear suspension

- Damaged carbon fiber layers of storage

Verification test of damaged storage ➔ Passed after 11,250 cycling tests at 103 MPa
Summaries

- Hydrogen Leakage Test (Single Failure Conditions)
  - Optimization of number of sensors and their locations is needed for effective detection depending on vehicle structure
  - In this particular model of HFCV SUV, some sensors are redundant
  - Interior sensors should be considered for detecting hydrogen entering from outside

- Rear Impact Test (Fuel System Integrity)
  - Exterior of storage was damaged due to deformation of suspension during impact
    - No noticeable strength degradation after endurance test
  - No malfunction in other storage components
  - Impact absorbing structure should be devised
Thank you very much for your attention!

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