Status of NHTSA’s Roof Ejection Mitigation Research

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Background

- Annual average 87 fatalities (FARS 2004-2017, coded as roof ejection path)
  - “Occupant Injuries Related to Rollover Crashes and Ejections from Recent Crash Data”
    Jingshu Wu et. al. 26th ESV, 2019

- Tests on production vehicles with laminated sunroof panels at 16, 20 km/h
  - 2009 Ford Flex (fixed); 2014 Ford CMax (fixed); 2013 Subaru Forester (movable)
    - 2016 SAE Government Industry Meeting
    - Paper at 25th Conference on Enhanced Safety of Vehicles (ESV), Detroit, 2017

- Tests on production and countermeasure* sunroof panels at 14, 16, 20 km/h
  - 2016 Ford F-150* (laminated - inner slider); 2010 Toyota Prius (fixed polycarbonate);
    2019 Aisin (laminated - outer slider)
    - Paper at 26th Conference on Enhanced Safety of Vehicles (ESV), Eindhoven, Netherlands, 2019
  - Lincoln MKZ (Protec II – outer slider)
    - Presented at 2020 SAE Government Industry Meeting

- Tests done on roof air curtains at 14, 16 and 20 kph, 6 locations
  - Hyundai-Mobis Roof Air Curtain (prototype curtain)
    - Presented at 2020 SAE Government Industry Meeting
Test Setup

- FMVSS No. 226 Impactor
- Featureless headform (40 lbs. [18kg])
- Displacement, speed from Linear Pot (LVDT)
- Accelerometer on the ram

Impact locations and speeds
- Speeds (14/16/20 km/h)
- Assumes
  - Left-right side are identical
  - Front-back are NOT identical
- Test each panel at
  - Front corner
  - Rear corner
  - Center
  - Mid-point of front transverse edge
  - Mid-point of rear transverse edge
  - At 2/3 of longitudinal edge
Summary of Hyundai Testing

- Prototype air curtain by Hyundai-Mobis
- Module with headliner and plexiglass on rear panel
- Bag deployed rear to front, however, had deployment issues so was hand opened for all tests
- Deployed along guide rods mounted on lateral edges, guide rings sewn to bag
- Failure modes included full and partial ripping of the bag from the ring at stitching
Autoliv Air Curtains

- Small crossover SUV frame, no headliner
- Air bag module mounted at rear of opening
- Bullet in rail deployment system
  - Five attachment points per side, sewn to curtain
  - Rails are stainless steel tubing mounted onto frame
- Latches at ends of rails to catch
Autoliv Air Curtains

- One Piece Woven material
- T-joint gas guide inflator with chambers as shown in video
  - 4 mol inflator
- Deployable roof air curtain
  - 14 full deployments, 14 hand opening tests
  - Deployments that failed were getting caught on middle support member
• Deployment of bag across opening took approximately 50ms

• It is not expected that hand opening would influence pressure in bag during impact

• Impact occurs at 6000 ms after transients have settled down (orange arrow)
Test Setup

- Impact locations shown in figure below
- Impacts at 14, 16 and 20 kph (at first contact with the deployed curtain)
- Mix of full deployments and hand opening bag before firing inflator
  - 14 full deployments, 14 hand opening tests
- 6 second delay between deployment/inflation and impact
Excursion Results

Excursions from closed glass panel (mm)

At 14 kph
At 16 kph
At 20 kph

\(^\text{=}\) = bag pre-opened

• Greater excursions on front panel than rear panel
• Excursions less in corners and on lateral edges
• Repeatability at front panel, front edge
  • Repeatable result when hand opened
  • Slightly different result from deployed (37mm)
Self-Deployed vs. Hand Opened

Hand-opened (224 mm)  Deployed (187 mm)

Front Panel Front Edge – 16kph
Comparison with Hyundai-Mobis Design

- Both bag designs contained headform when bag deployed correctly
  - Hyundai bag smaller and did not cover full opening, Autoliv bag larger and covered full opening
- Both designs in development but show feasibility for use with the current procedure
- Excursion limits may need adjustment for deployable curtains with open portals
Comparison with Hyundai-Mobis Results

- Similar excursion results between Hyundai and Autoliv on front panel
- Both OPW results, 6 second delay, all Hyundai bags were hand opened, only half of Autoliv were hand opened (indicated with ^)
- Different chamber pattern and inflator, different opening size and bag size (shown to scale above)
- Front glass impacts on Hyundai kept plexiglass on rear panel, Autoliv did not have any plexiglass panels
Curtain air bags had similar forces and energy to each other.

Curtain air bags had similar forces but higher excursions than laminate movable sunroofs.
Excursion Comparison (All Vehicles)

- Air Curtains had the highest ram displacements
- Prius had the smallest displacement
- The Aisin panel detached from the supports
Overall Observations

- Movable panels with good attachment designs can have excursion <100mm
  - MKZ had metal rails, pins and cam
- Air curtains feasible for preventing ejection but still in development
- Roof air curtains produced similar headform forces and higher excursions than laminate movable sunroofs
- All components in load path need to be designed for occupant containment
  - Rail, rail inserts, bonding to glass, glass/plastic strength
- Smaller excursions may lead to higher head and neck forces
Data can be found at: Component Test Database (COMDB)
Test Numbers for Autoliv tests: c01826 through c01888