講演番号	357

Development of Open Top Air Body Structure Using Hot Blow

Do Hoi Kim [1)] Kang Chul Lee [1)] Golam Ahmed [2)] Forrest Eddings [2)]

Dhananjay More [2)] Vinaya Kumar Rachala [2)] Vinaya Kumar Pellerla [2)]

1) Hyundai Motor Company
150, Hyundaiyeonguso-ro, Namyan-eup, Hwaseong-si, Gyeonggi-do,445-706, Korea (E-mail: hephzibar7@hyundai.com)
2) Hyundai America Technical Center Incorporation,
6800 Geddes Road Superior Township, Michigan 48198, United States

KEY WORDS: **Open Top Air, Hot blow, Tubular Structure, Roof Crush, IIHS small overlap, Stiffness**

This research develops hot blow-formed pipe technology for open-air top vehicle structures targeting North American consumers. The detachable roof system requires strategic structural modifications while maintaining performance parity with conventional monocoque vehicles.

Design Challenges and Solutions: Open-air top configurations present three primary challenges: roof detachment mechanisms necessitate reduced cross-sectional roof side rails; removable roof designs affect rail configuration; and maximizing open-air sensation requires minimal cross-sectional dimensions. To address these constraints while maintaining structural integrity, hot blow-formed pipes without flanges are integrated into the body structure. This advanced forming technique creates variable cross-sections (19.6% expansion rate) with high strength levels (approximately 150 kgf-class), enabling geometric adaptation within limited space constraints.

Two-Phase Development: Phase One developed closed-form structures by integrating hot blow-formed pipes within side outer panels. The design incorporates unified pipe structures extending from A to C/D pillars with optimized welding strategies for efficient load transfer. Phase Two addressed market demand for open-form structures with visible pipe geometry, exemplified by B and W vehicle platforms.

Structural Design Features: The modified design reduces roof side rail cross-sections by 25 mm to accommodate sealing structures. A unified polygonal pipe concept integrates A to C roof side rails for improved body strength and rigidity. Strategic welding at front sections (inner/outer panel interfaces) and rear sections (D-pillar and quarter inner panel) facilitates efficient load transfer. Increased corner radius of cross members enhances joint rigidity and roof panel load distribution.

Performance Analysis: Three critical performance areas were evaluated: crash performance, ceiling strength, and torsional rigidity.

Crash Performance: Front and offset crashes demonstrated equivalent performance to baseline vehicles. However, small overlap crashes revealed inferior performance due to high-strength pipes restricting A-pillar deformation, causing upper C-pillar buckling. Solutions included linearizing pipe geometry and reinforcing side sill sections for underbody deformation control.

Roof Crush: Initial designs showed SWR (Strength to Weight Rate) reduction because robust roof side rails resisted deformation, forcing B-pillars to directly transmit loads. Improvements through enhanced connectivity between center and side roof rails increased SWR from 3.76 to 4.2. Additional C-pillar-connected roof rails were incorporated to meet torsional rigidity requirements.

Torsional Rigidity: Open-top variants exhibited only 60% or less of baseline vehicle rigidity due to roof absence. A target of approximately 70% baseline rigidity was established. Achieving this required additional welds between body frame and tubular reinforcements, plus reinforced roof rail junctions to resist shear stress.

Manufacturing Implementation:

Hot blow-formed pipes were developed collaboratively with HATCI. Variable cross-sections were designed with 19.6% expansion rates, with forming simulation analysis addressing wall thickness reduction and rupture zones. However, manual pre-bending (rather than automated processing) resulted in dimensional tolerance challenges. Automated bending implementation is anticipated to improve tolerance performance significantly.

Conclusion:

While closed-form designs initially demonstrated performance inferiority compared to monocoque structures, improvement measures achieved equivalent crash performance. However, rigidity remained inferior due to roof absence and rail cross-sectional reduction. The research confirms that comprehensive durability validation accounting for rigidity reduction is necessary for similar open-air top SUV development. The open-form structure, featuring exposed pipe geometry appealing to North American consumers, requires integrated development across design, production technology, and core competencies(Fig.1).

Fig. 1 Completed Hot Blow-Formed Pipe