GREAT DESIGNS IN STEEL

DEVELOPMENT OF A TAILOR WELDED HOT STAMPED SIDE FRAME MEMBER

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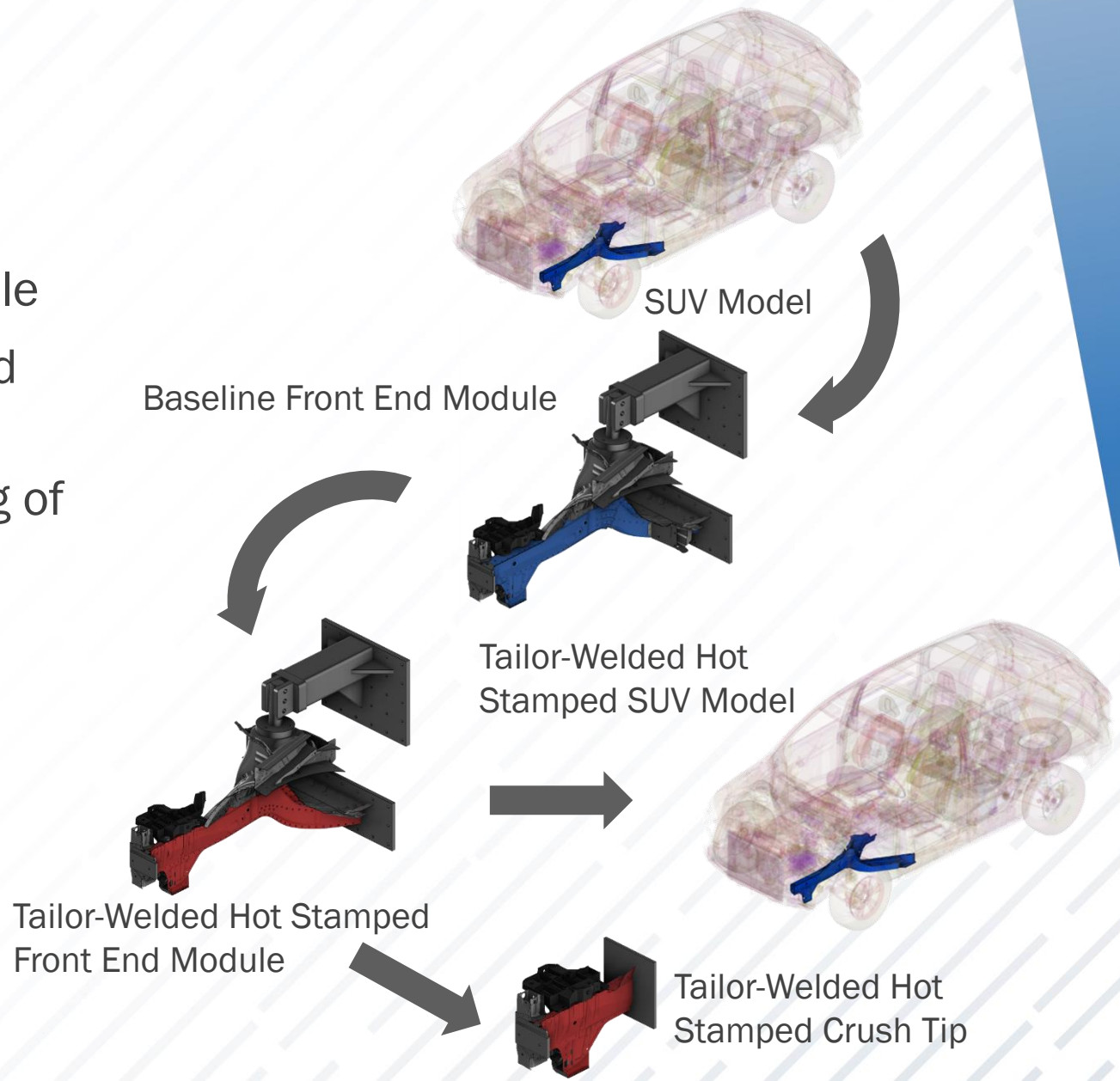
OVERVIEW

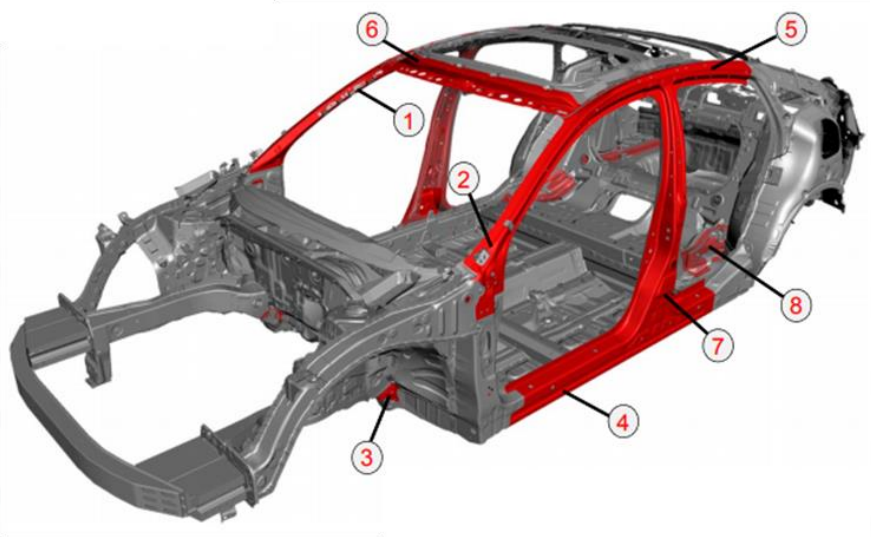
- Background and Project Objectives
- Developing a Baseline Front End Module
- Designing a Tailor-Welded Hot Stamped Side Frame Member
- Manufacturing, Fabrication and Testing of Hot Stamped Crush Tips
- Summary and Outlook



BACKGROUND

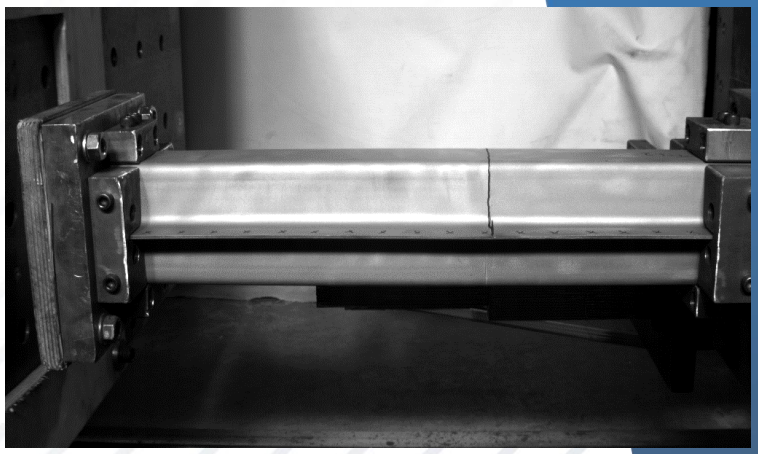
Hot stamping steels have been incorporated into occupant compartment intrusion resistant zones, but there is a reluctance to include UHSS in frontal crush structures due to relatively low ductility in the fully-quenched state.

Hot stamped components in the 2016 Honda Civic [1]



Fully martensitic Usibor® 1500-AS crush rail [2]

Ductibor® 500-AS/Usibor® 1500-AS [3]



Ductibor® 1000-AS for frontal crush?

[1] American Honda Motor Co., "2016 Civic: New Model Body Repair Information," November 2015. [Online]. Available: https://www.civicx.com/threads/2016-civic-body-technology-construction-and-repair-bulletin.721/. [Accessed 1 February 2019].

[2] K. Omer, L. ten Kortenaar, C. Butcher, M. Worswick, S. Malcolm and D. Detwiler, "Testing of a Hot Stamped Axial Crush Member with Tailored Properties - Experiments and Models," *International Journal of Impact Engineering*, vol. 103, pp. 12-28, 2017.

[3] C. Peister, "Axial Crush Performance of Hot Stamped Tailor Welded Blanks," University of Waterloo, Waterloo, 2019.

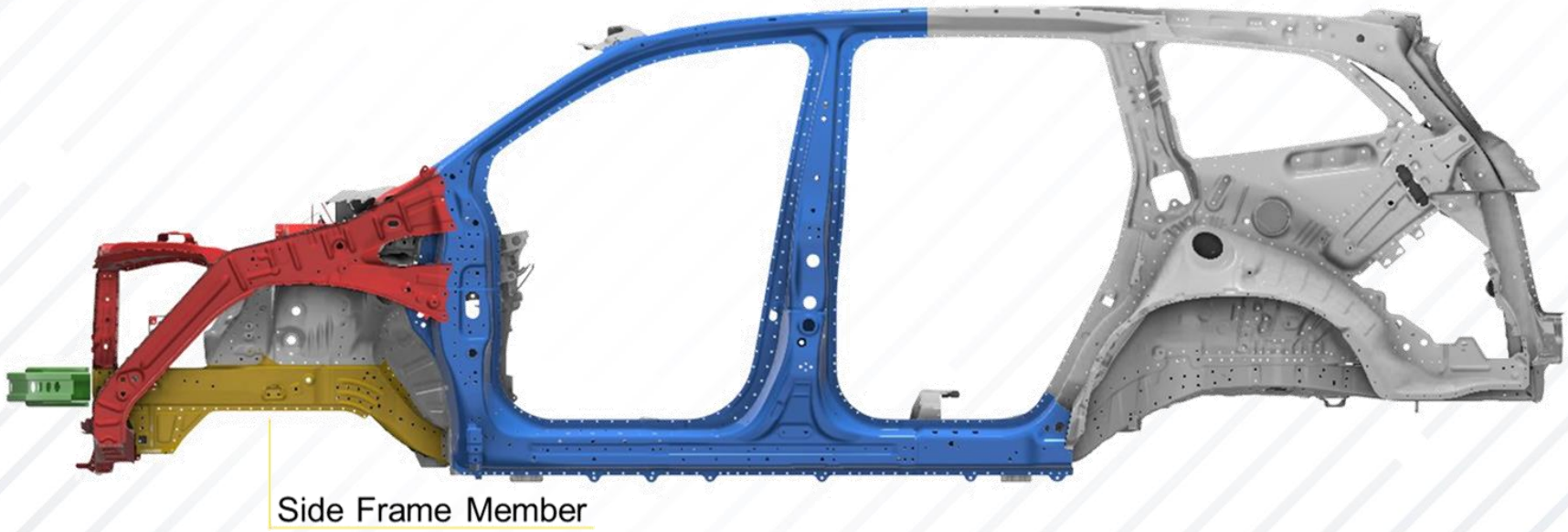
PROJECT OBJECTIVES

Develop a representative demonstrational geometry of a production SUV frontal impact structure.

- Particularly the side frame member (front crush rail)

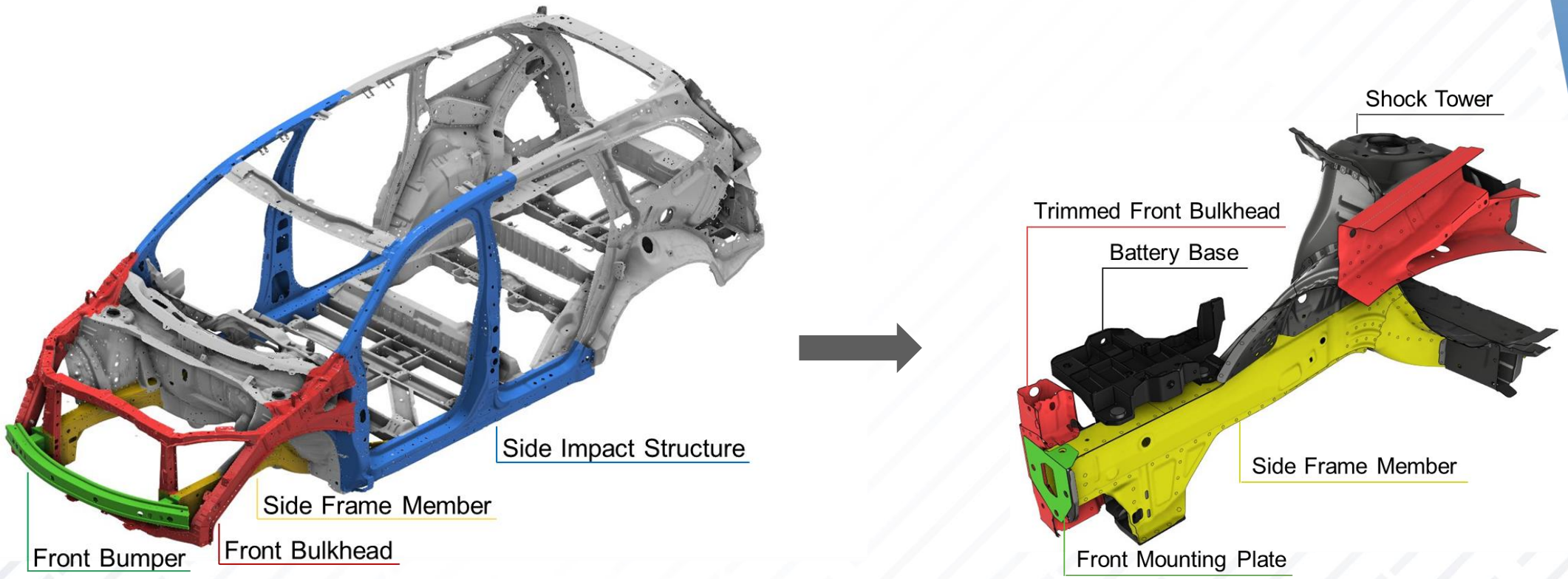
Evaluate the potential weight savings through implementing a Usibor® 1500-AS / Ductibor® 1000-AS tailor welded blank combination.

Demonstrate the appropriateness of 1000 MPa strength material in axial crush structures.



DEVELOPING BASELINE FRONT END MODULE

A reduced BIW structure was developed by stripping away components from the BIW structure until the minimum required to constrain the side frame member were found.

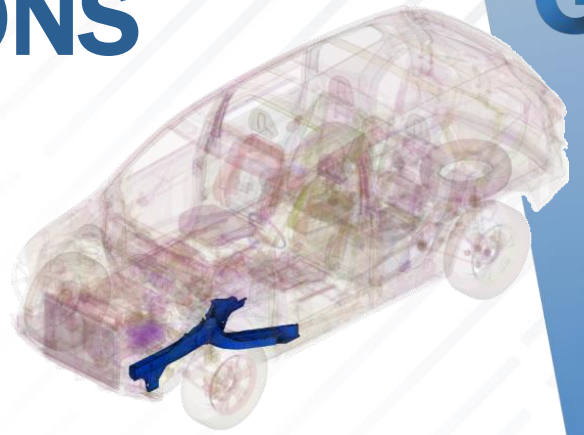


Approach was to develop a baseline production build JAC590 demo structure:

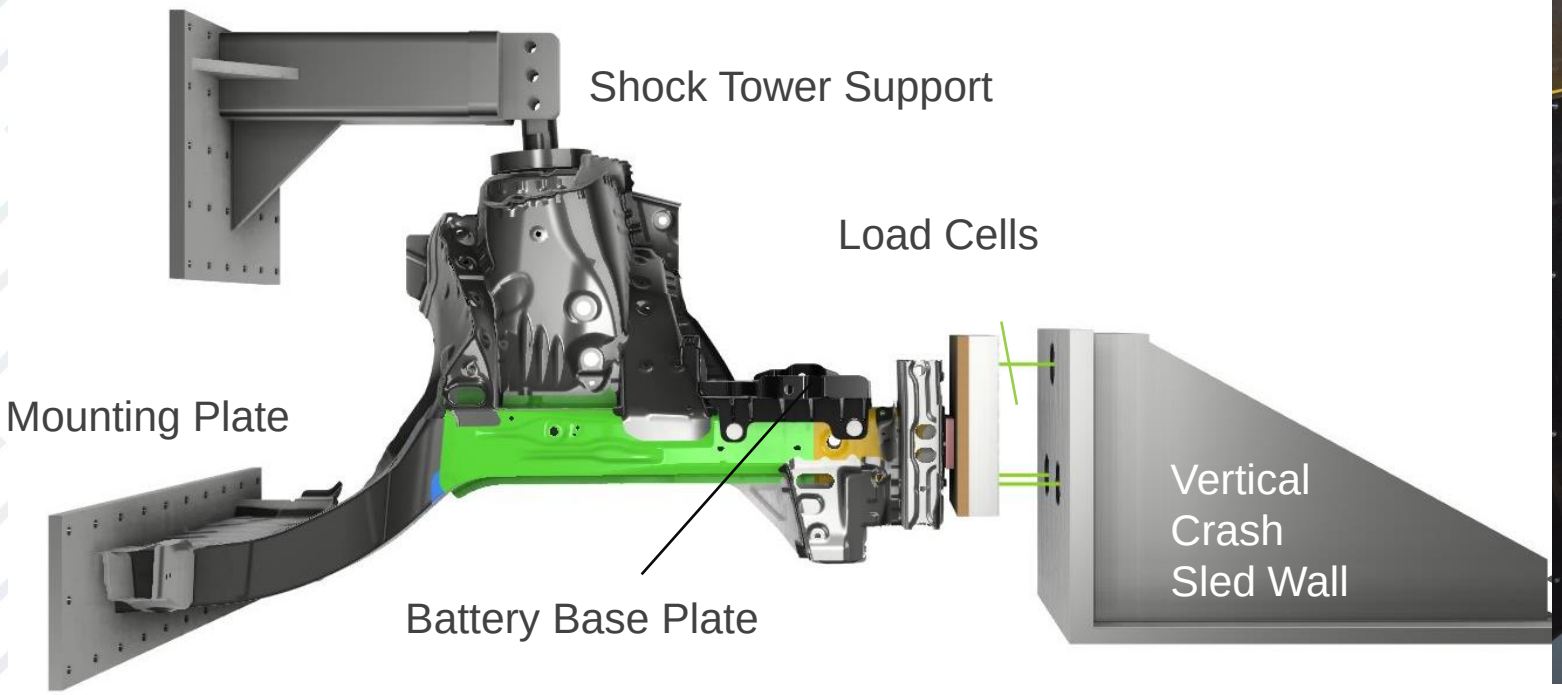
1. Amenable to lab testing while matching in-vehicle response
2. Serve as a surrogate to evaluate hot stamped Ductibor® 1000-AS build

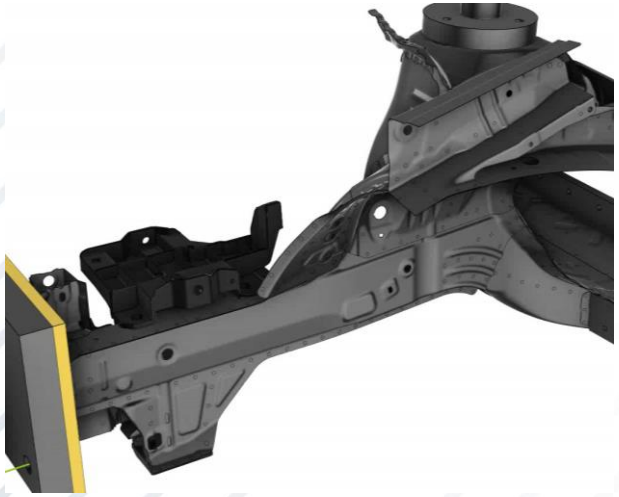
DEVELOPING DESIGN SPECIFICATIONS

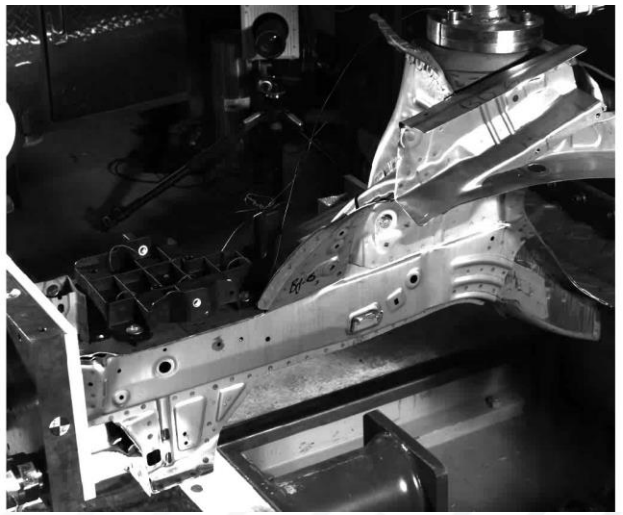
US-NCAP FULL WIDTH RIGID BARRIER SUV FRONTAL CRASH MODEL



BASELINE MODULE SIMULATE, FAB AND TEST

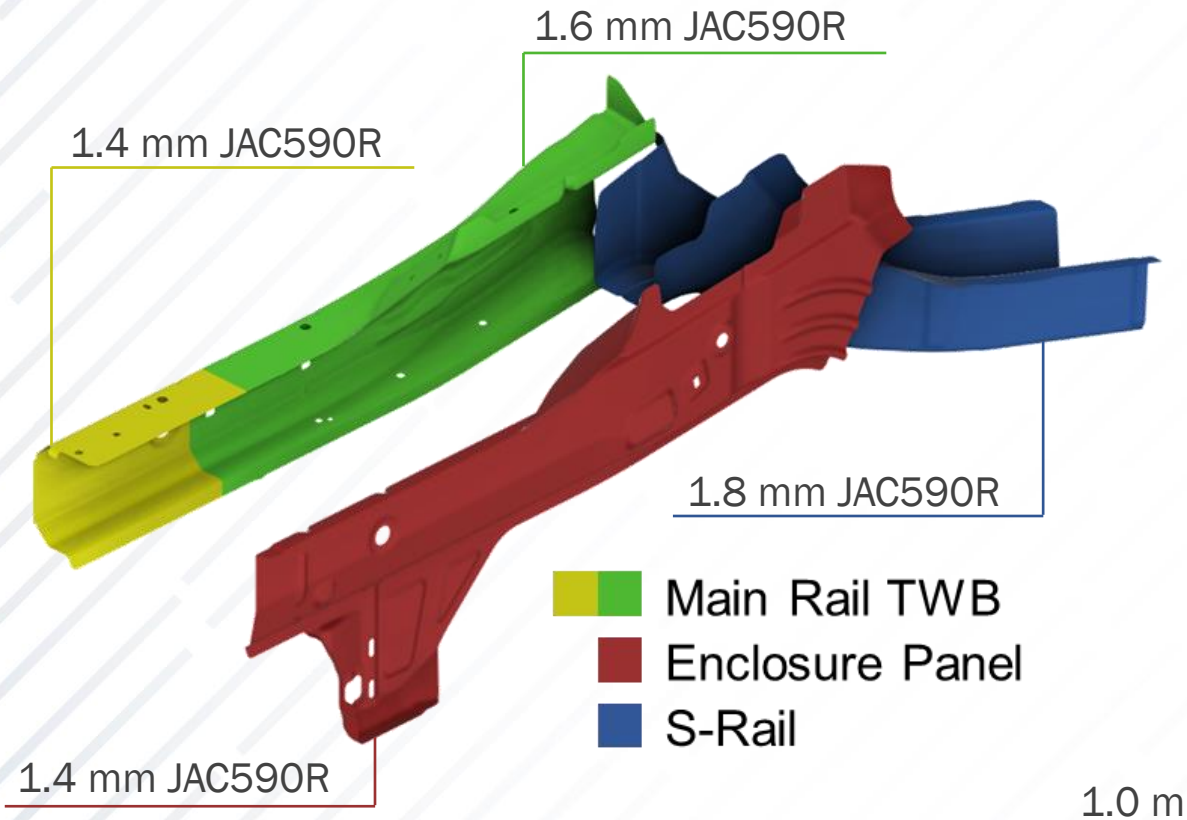


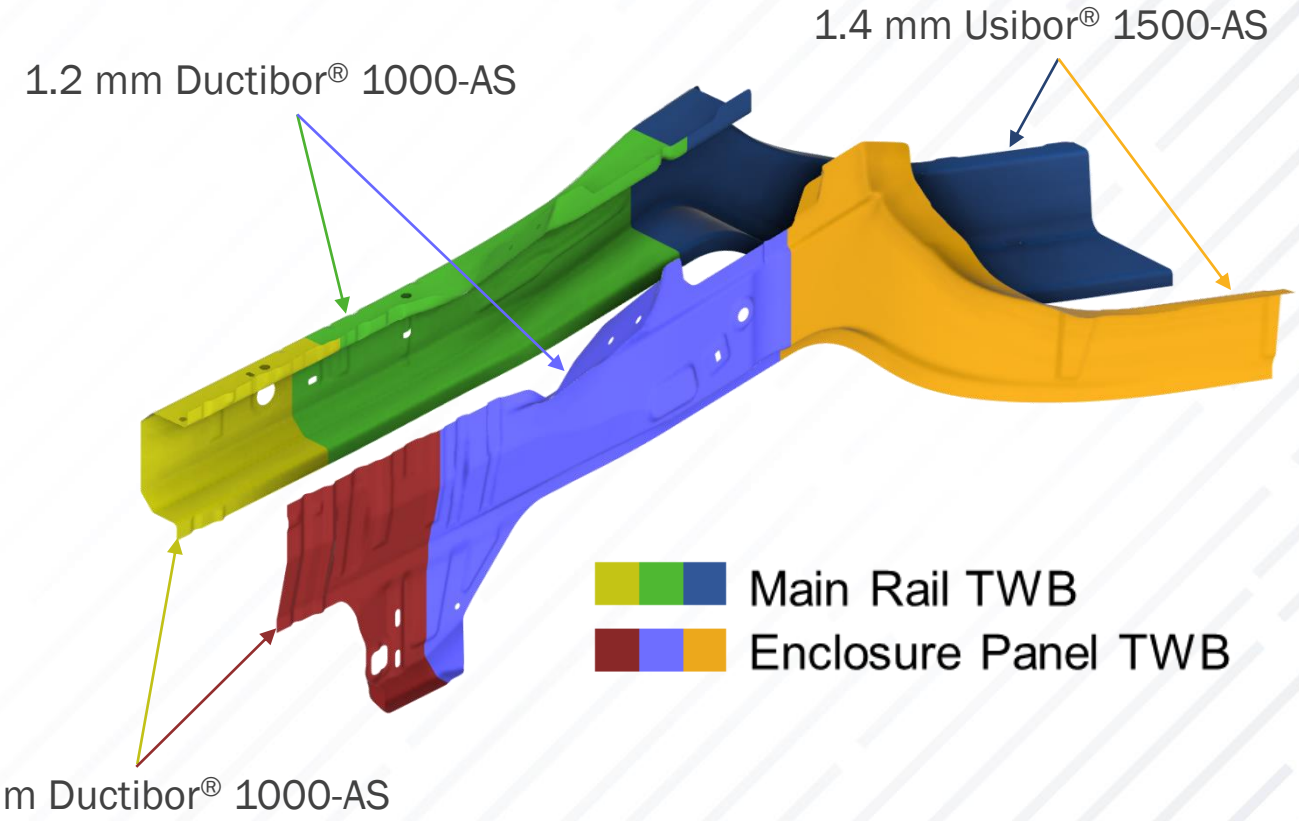




Very good agreement between side frame collapse modes and load-displacement (relative to full vehicle response) once impact engagement fixtures implemented to match effect of bumper torque and crush box in full vehicle.

INITIAL HOT STAMPED TWB DESIGN





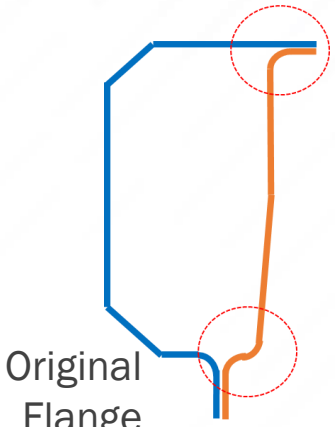
The TWB design requires 1 less component and 6 less spot welds to assemble.

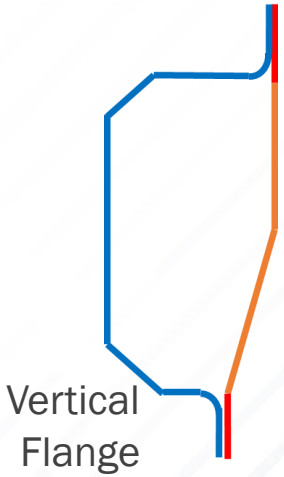
DESIGN EVOLUTION

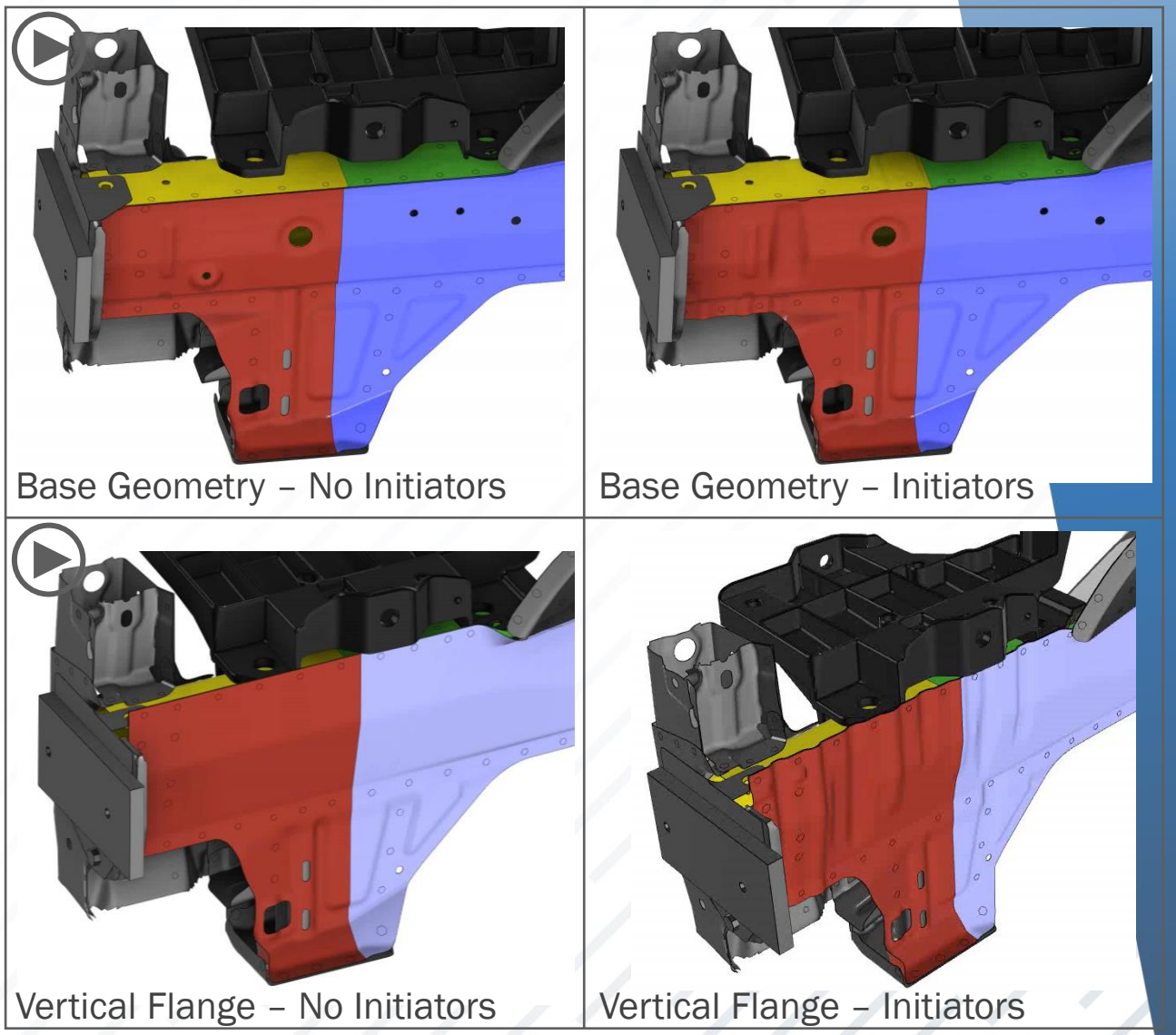
Very detailed CAE models were developed with extensive parent metal and weld fracture calibration.

Severe spot-weld failure was observed in the base geometry flange, with and without fold initiators.

The flange orientations and section profile were adjusted to better approximate a half-hat channel - spot-weld failure severity is significantly reduced and further reduced with progressive fold initiator additions.

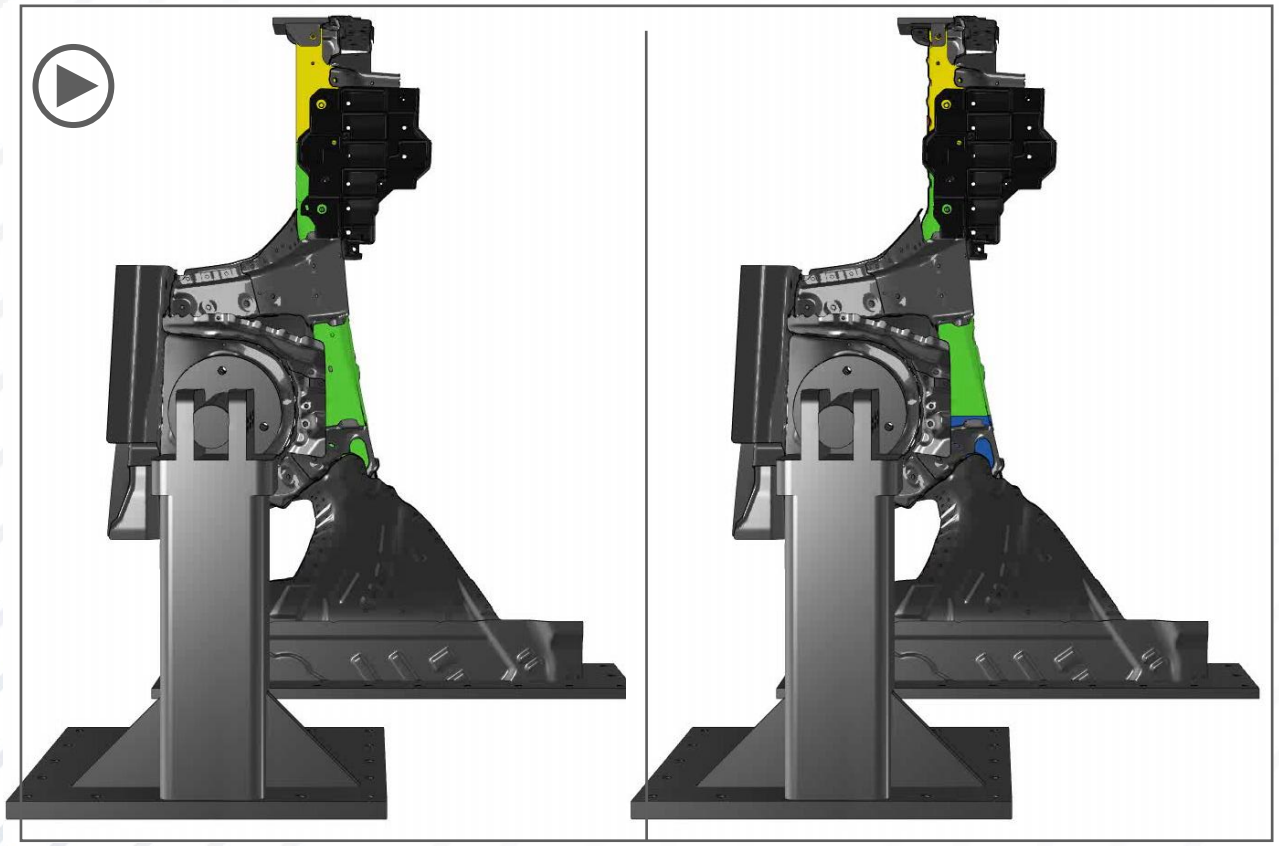




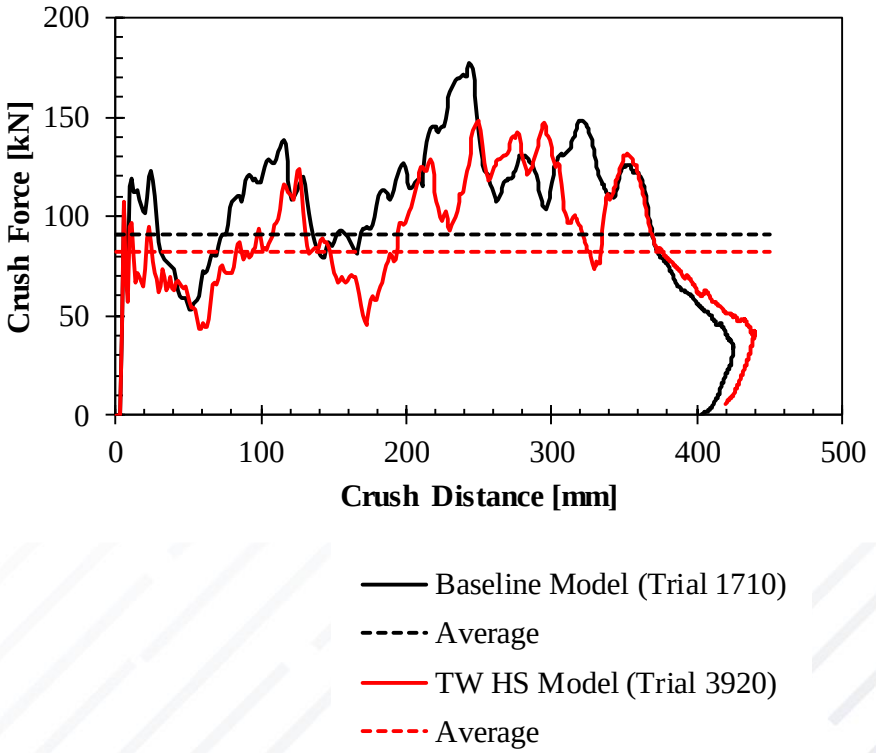


COMPARISON TO BASELINE SIDE FRAME

The tailor-welded hot stamped side frame member exhibits similar crush response and crush forces relative to the baseline production front end module.

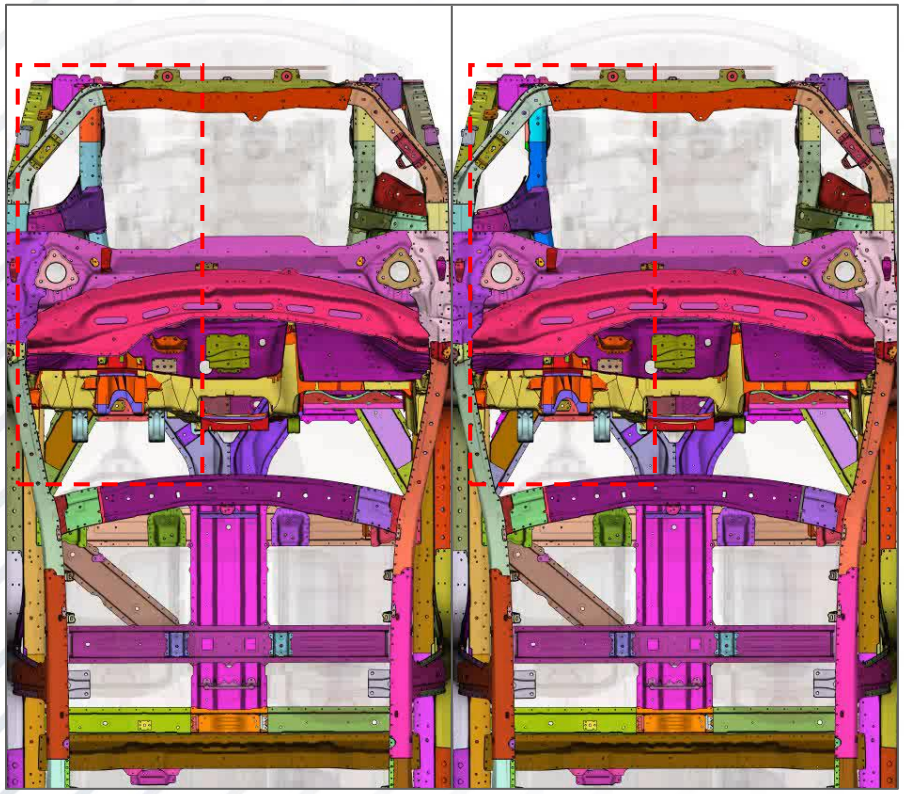


Baseline JAC590 Hot stamped Ductibor® 1000-AS



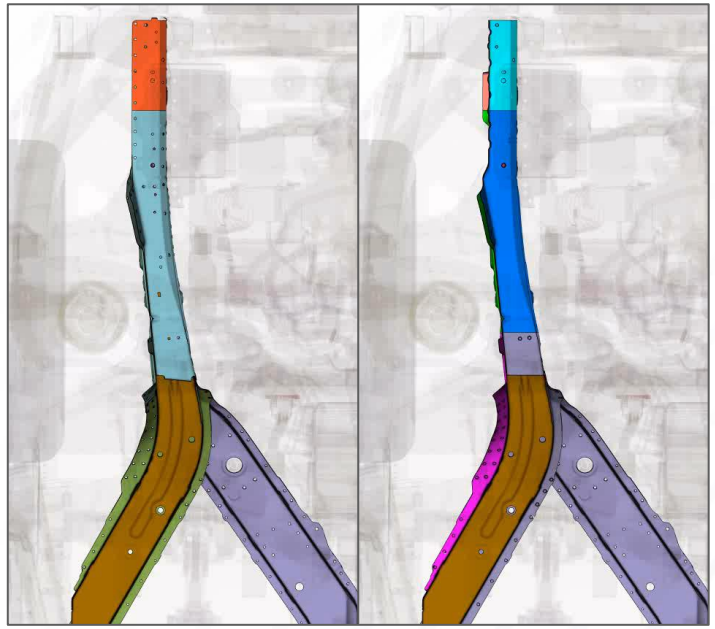
HOT STAMPED SIDE FRAME IN SUV

The tailor-welded hot stamped side frame member was substituted into the SUV model in place of the production driver's side frame member.



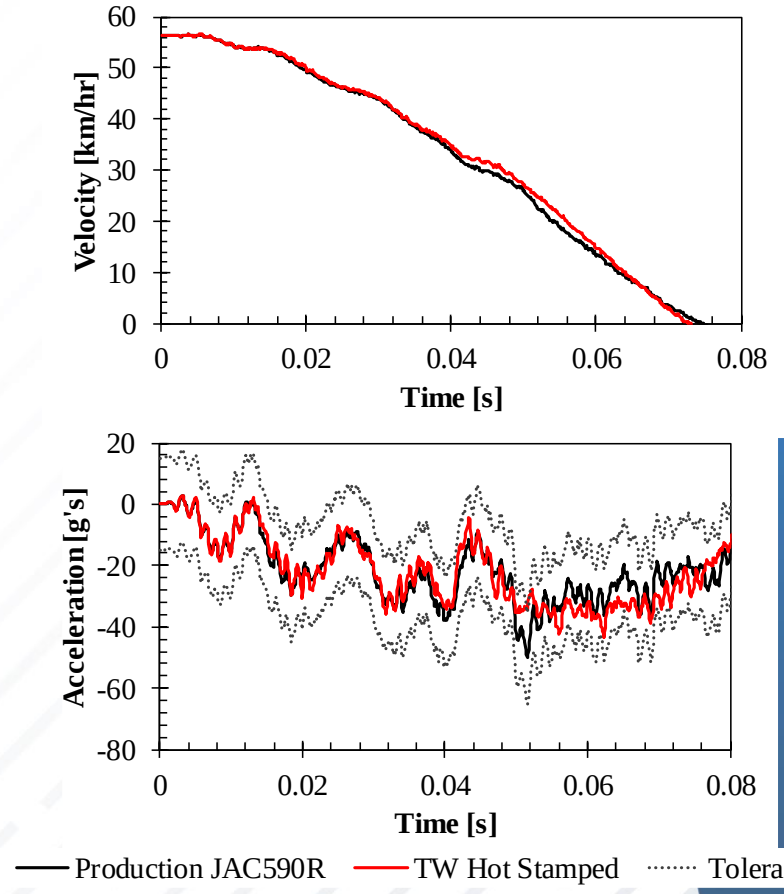
Original
Production

Hot Stamped
Driver's Side

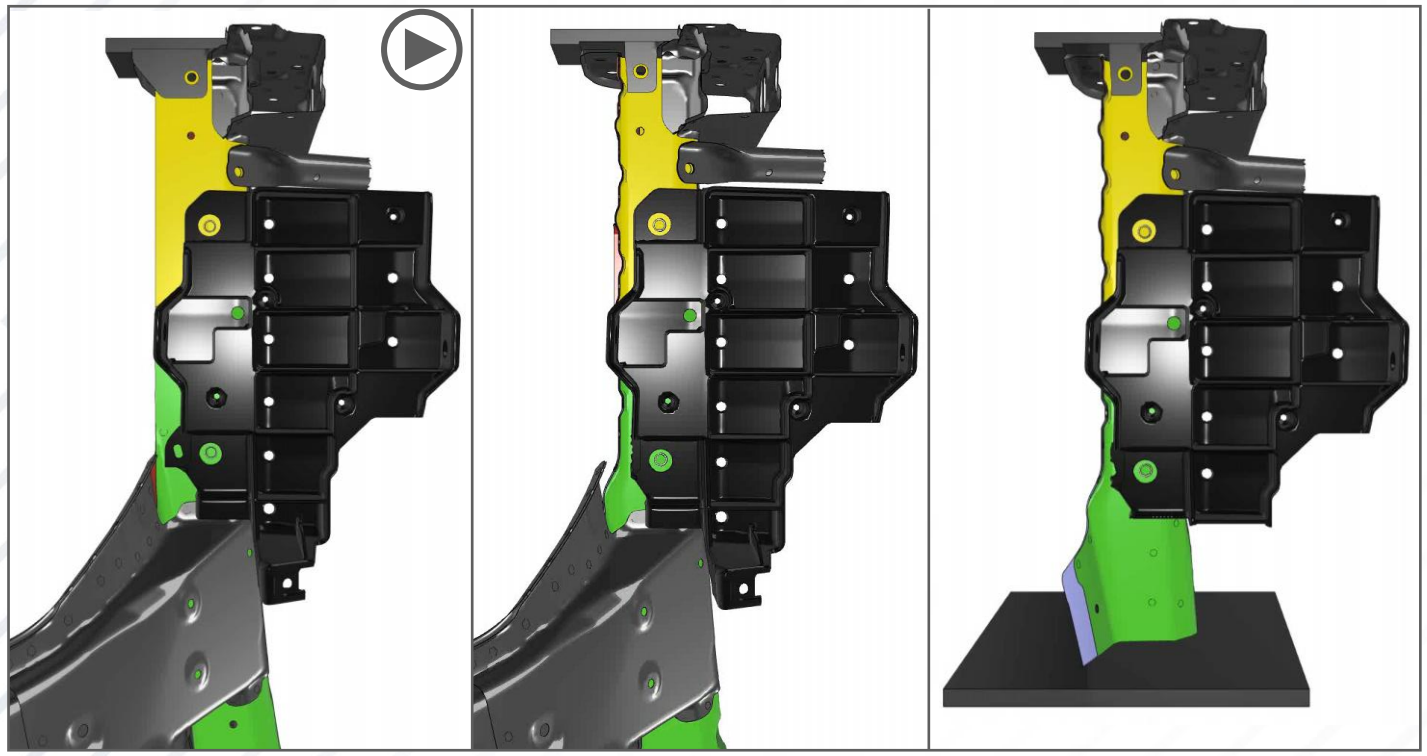


Original
Production

Hot Stamped
Driver's Side



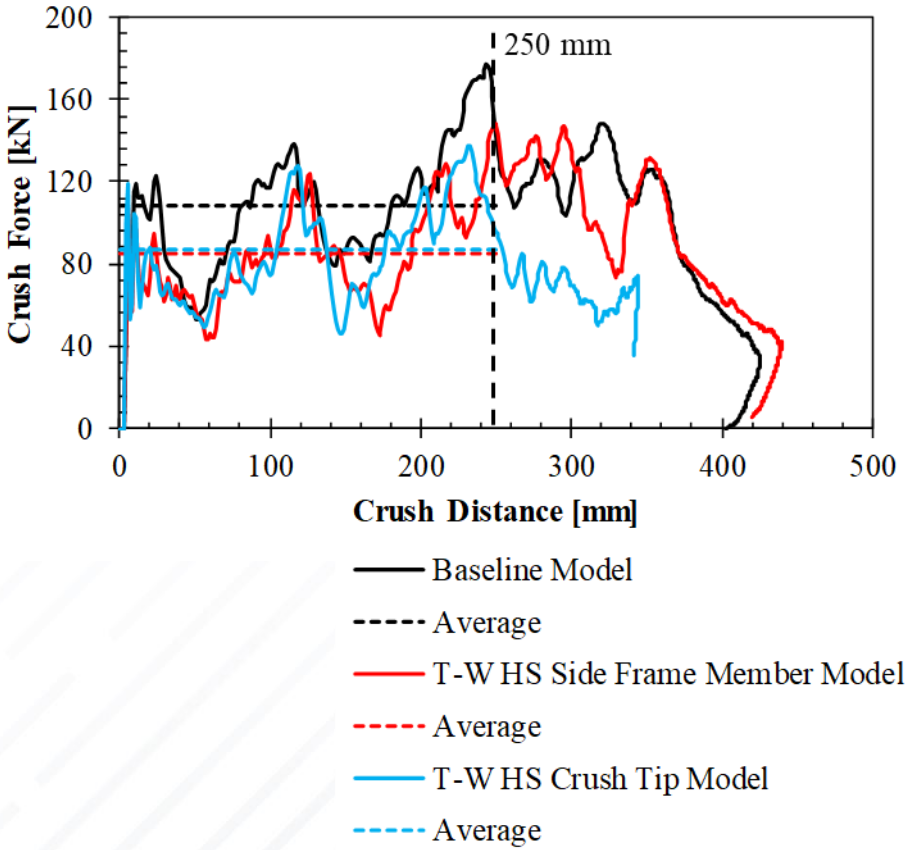
VALIDATION – CRUSH TIP BUILD



Baseline
Production Material

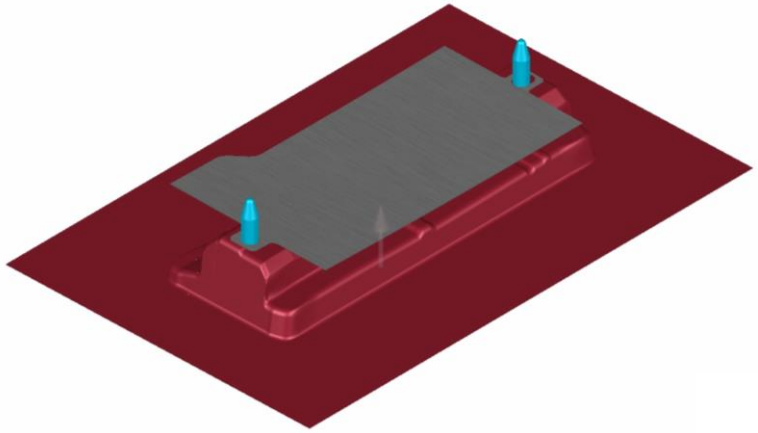
Tailored – Full
Hot Stamped Material

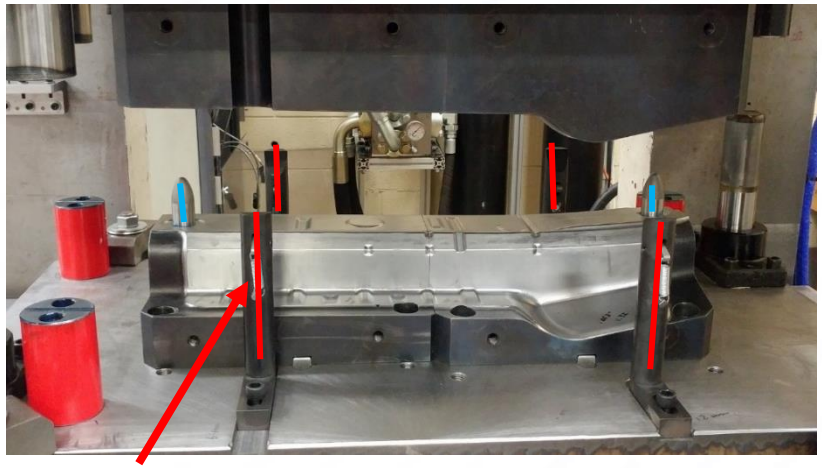
Tailored – Crush Tip
Hot Stamped Material



Crush tip displays similar crush response (modes) and forces over the initial 250 mm of crush.

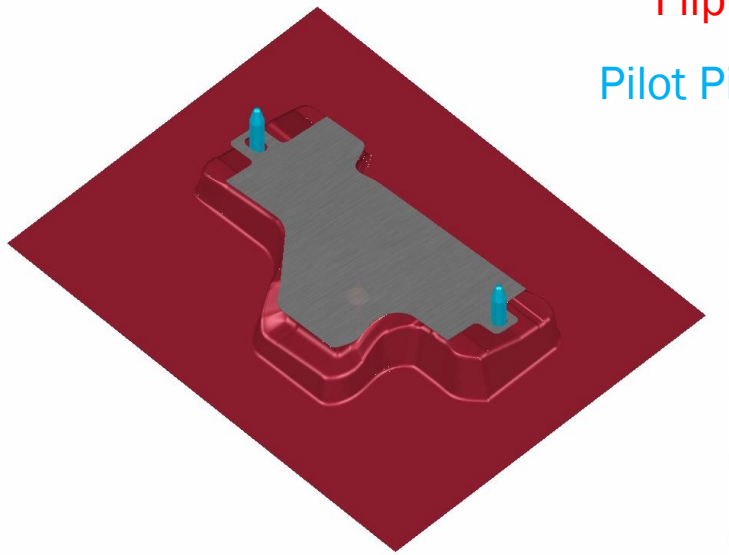
HOT STAMPING MODEL AND TOOLING

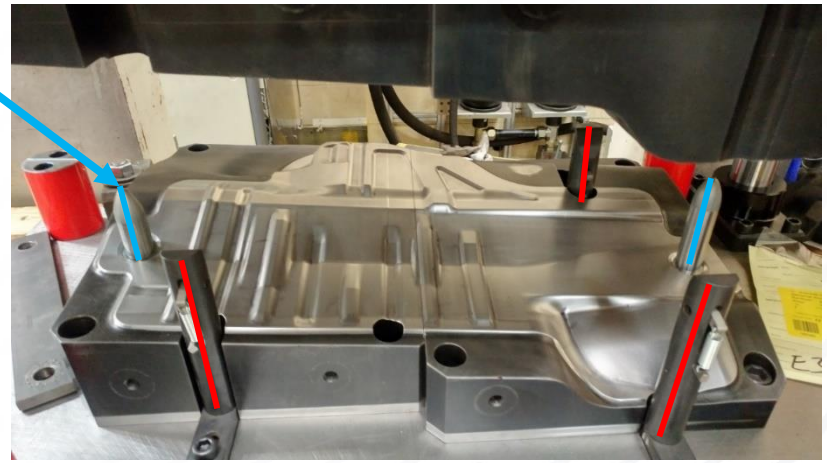




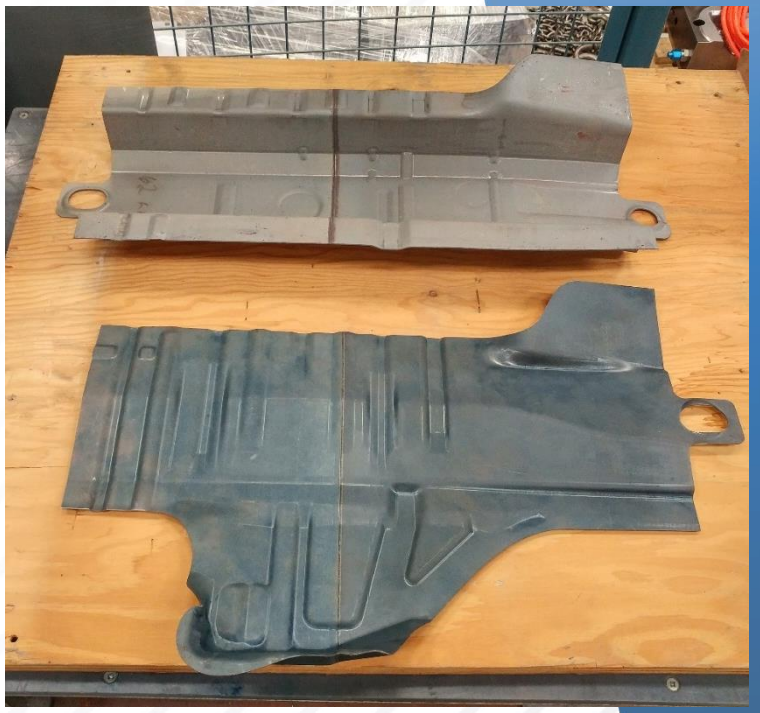
Flipper Gauges

Pilot Pins





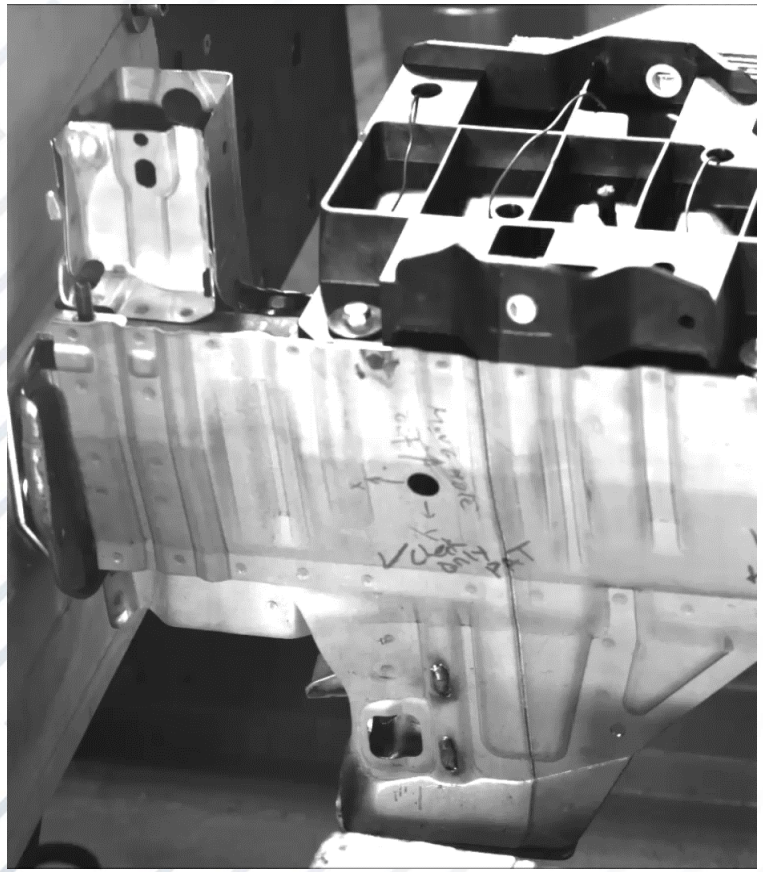
Main Rail

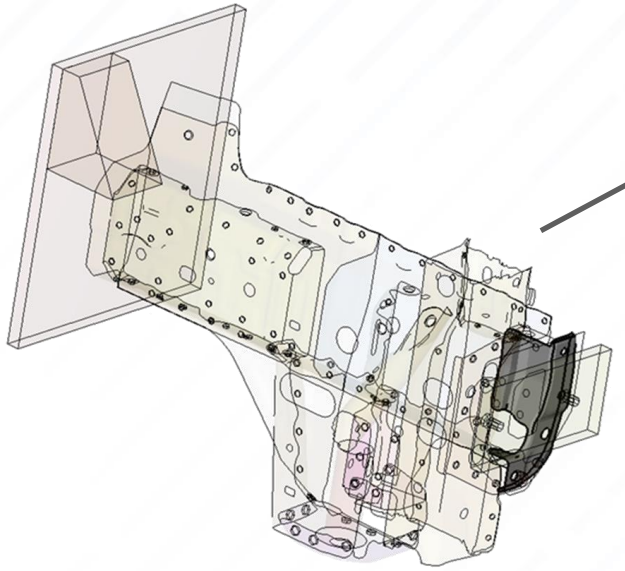


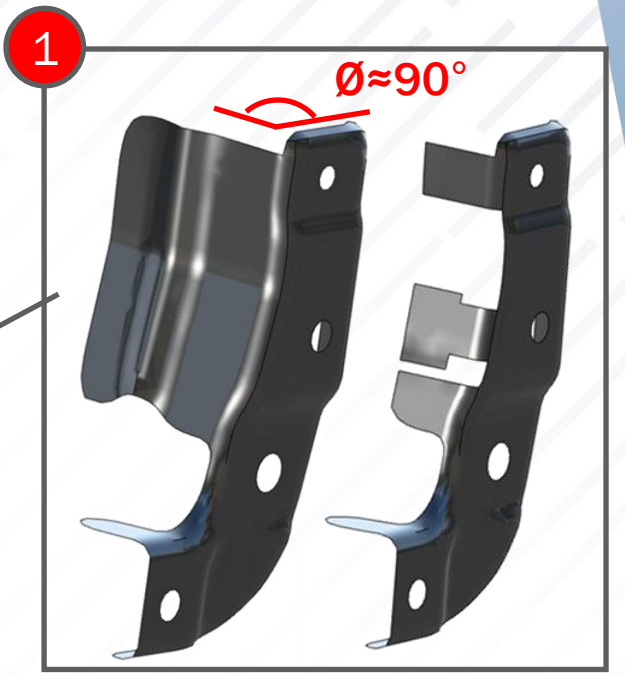
Enclosure Panel

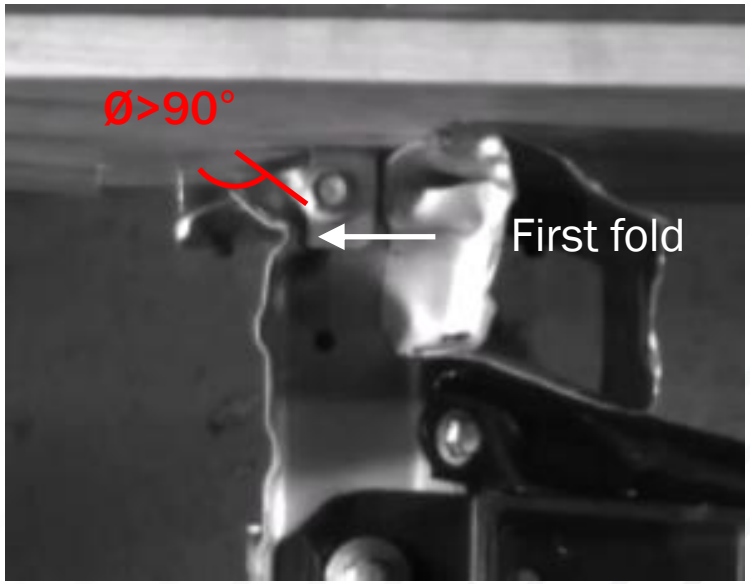
INITIAL TRIALS – CORRECTIVE MEASURES

Initial experiments exhibited excessive spot-weld unzipping in baseline build









Root cause was tied to a front bracket that was not folding (flattening)

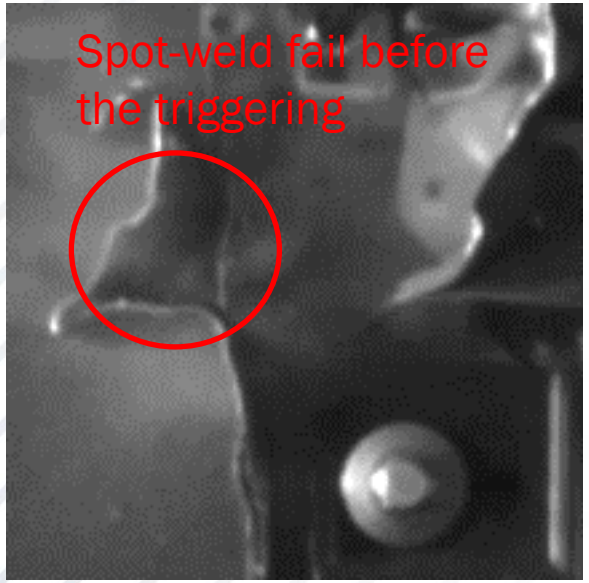
1. Fingers were machined into bracket which enabled first fold to trigger
2. Spot-weld schedule modified to grow weld nugget ~30% strength increase

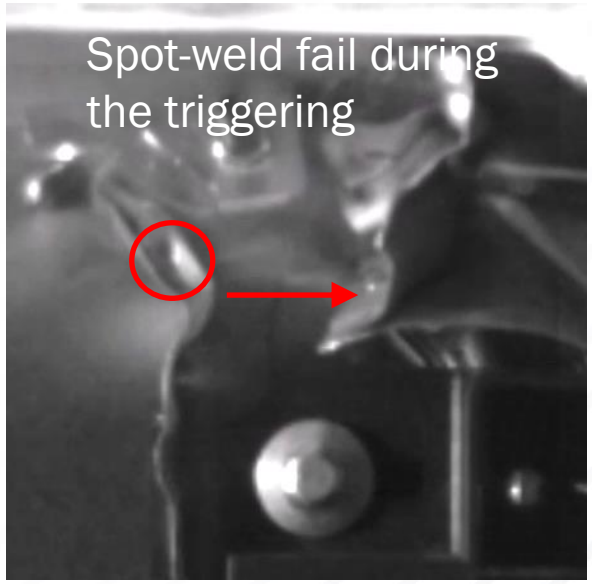
EVALUATION CRITERION

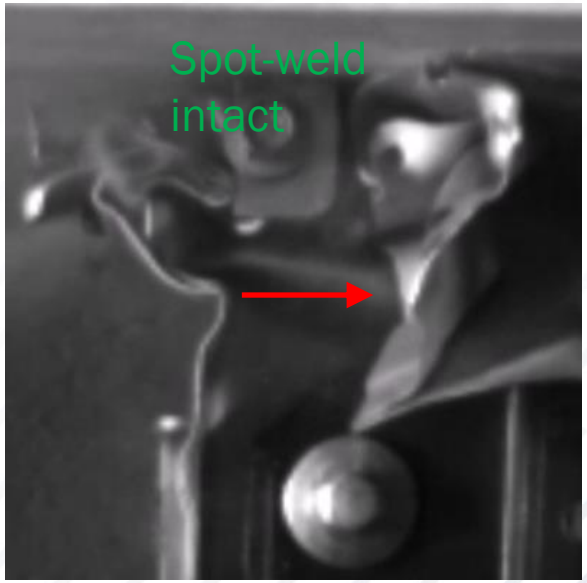
For the fold initiators to function, the adjacent spot-welds need to hold.

The adjacent spot-welds can fail either

1. Prior to the triggering of the fold initiator → unzipping of spot-weld
2. Or during the triggering of the fold initiator → instability
3. Or after the triggering of the fold initiator → progressive folding







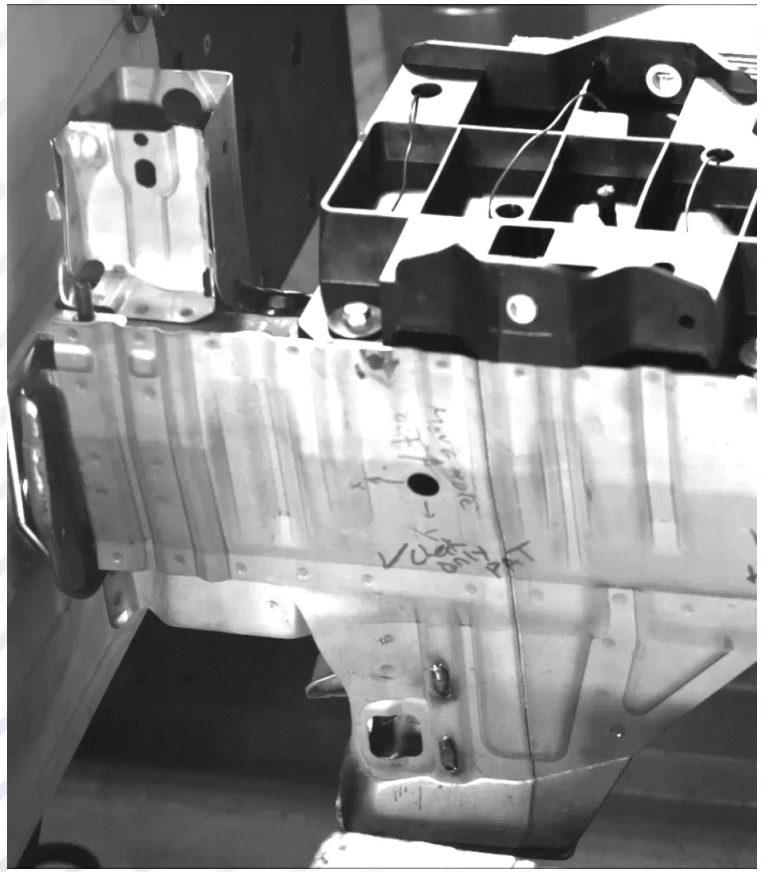
TOP VIEW

Legend: Spot-weld failures

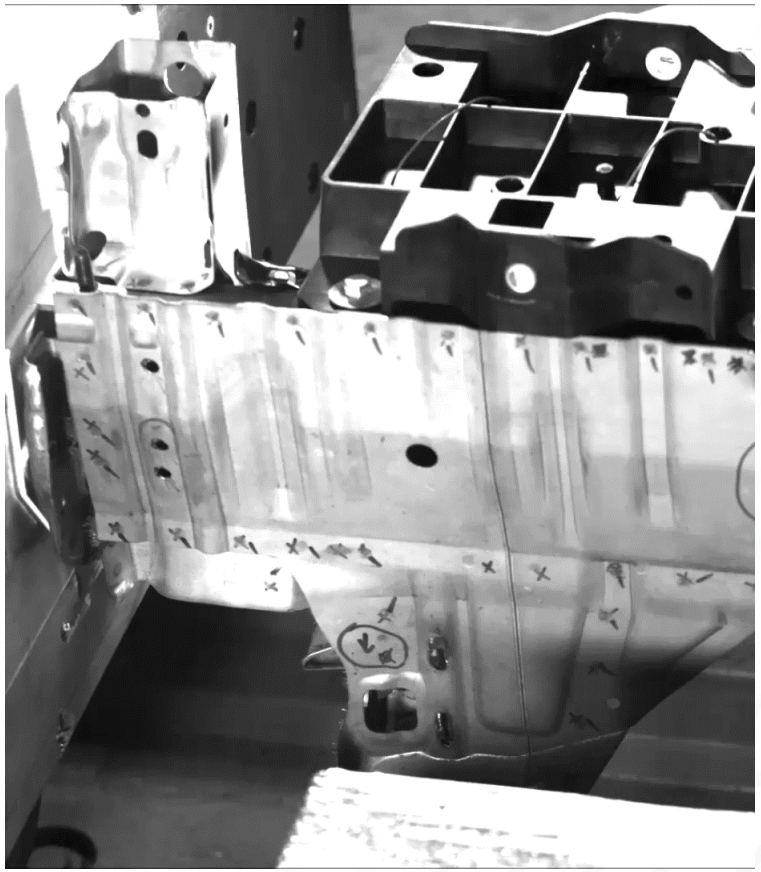
- Prior to triggering of fold initiators
- During triggering of fold initiators
- After triggering of fold initiators (or no failure)
- * Spot-welds unzipped

Note:
- Spot-weld fails referred to here are those in the front region where 1.0 mm sheets are welded.
- All test specimens were subject to the impact velocity of 27.5 km / hr

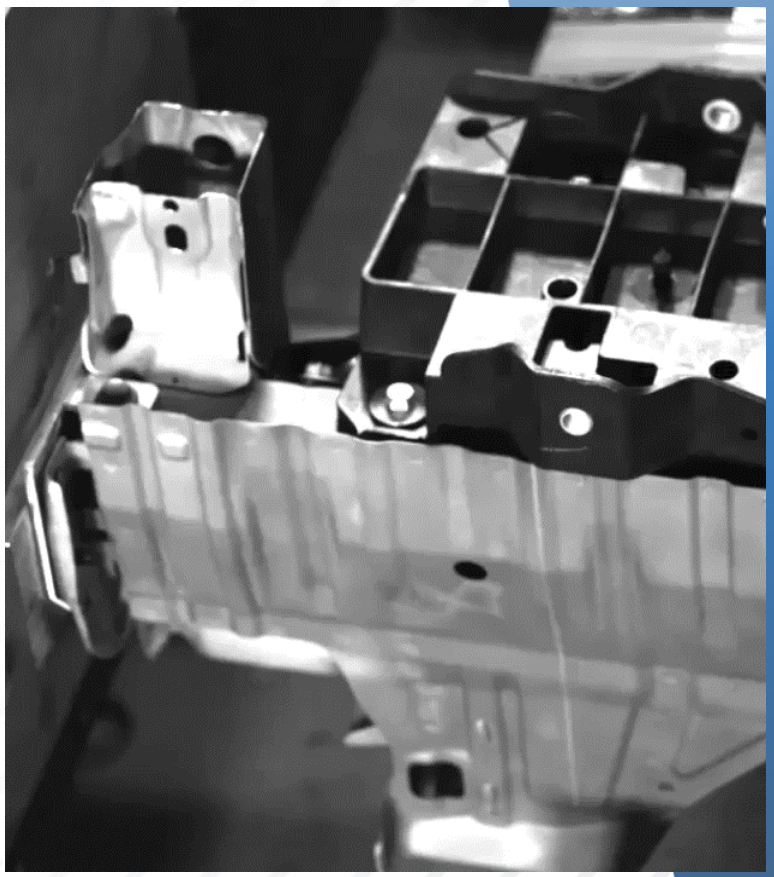
VIDEO COMPARISON



Baseline

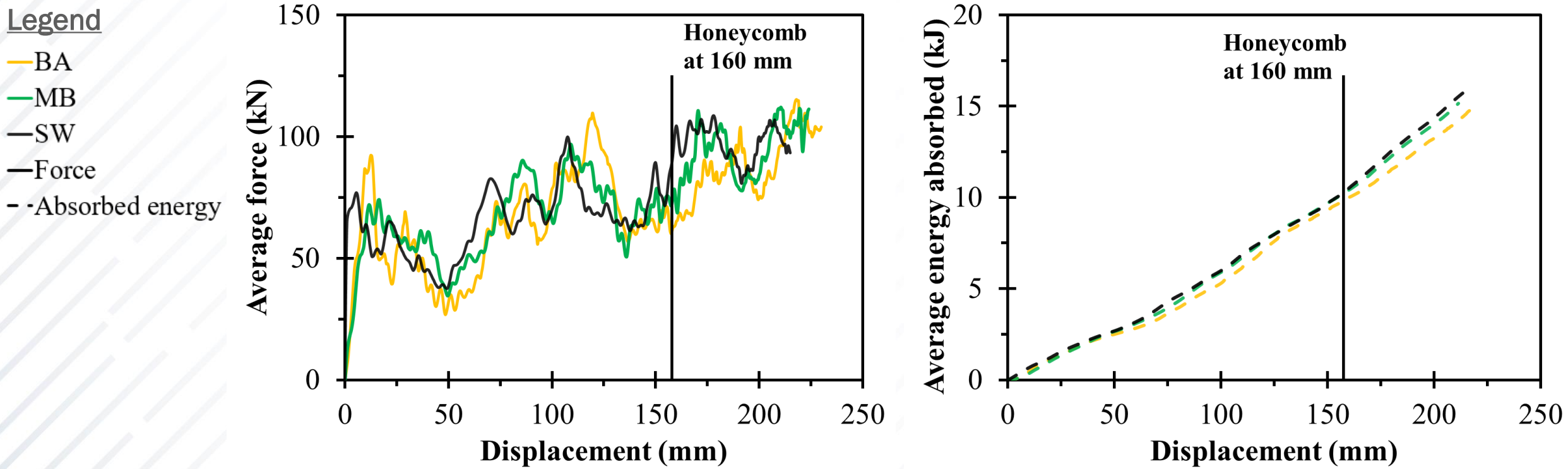


Machined bracket



(Machined bracket + increased spot-weld strength)

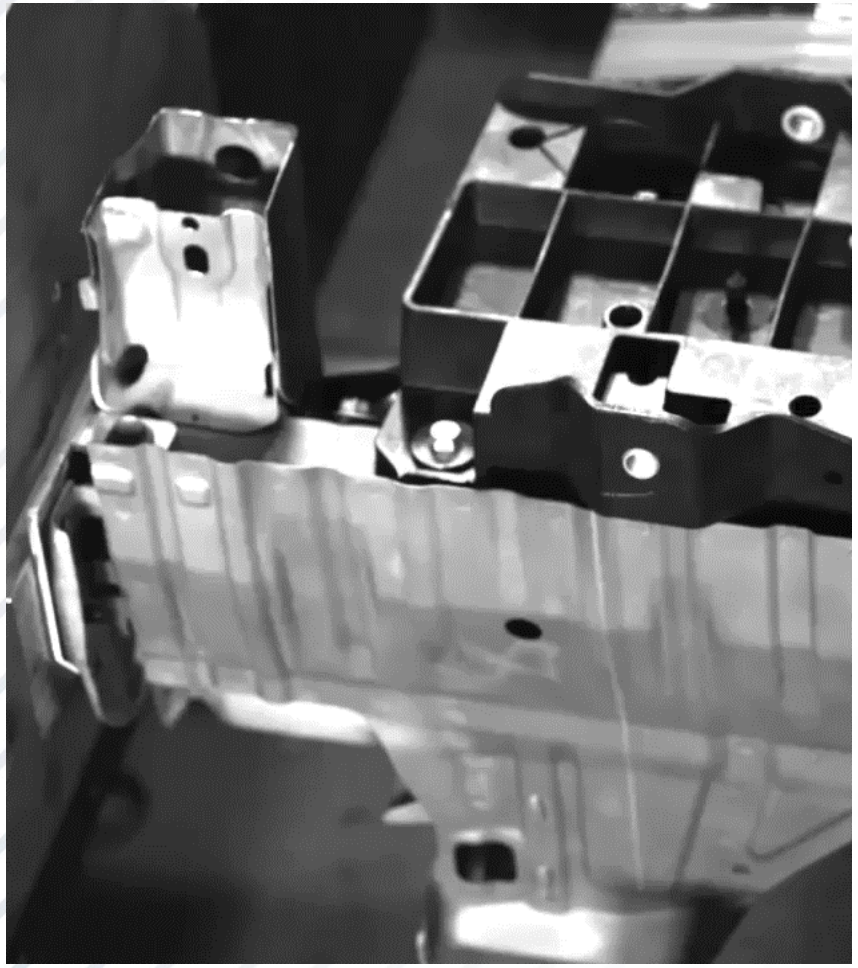
STRUCTURAL RESPONSE

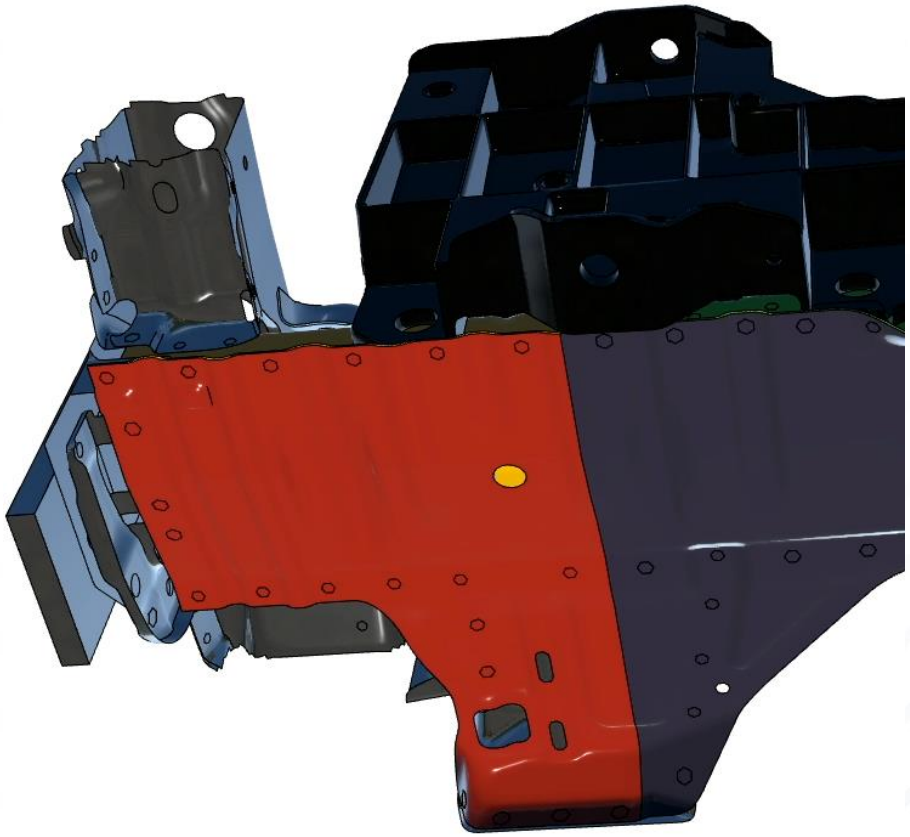


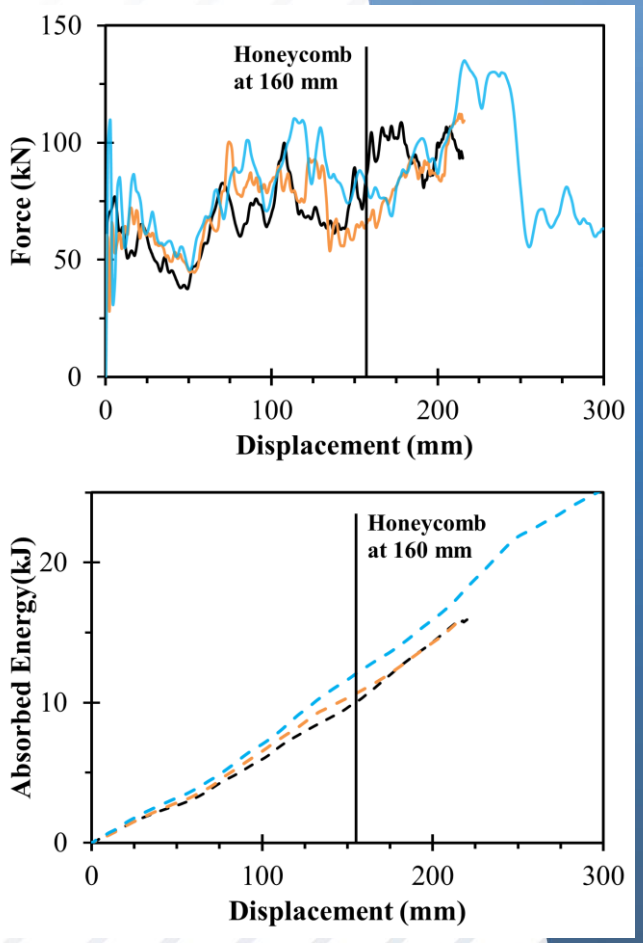
Rather interesting outcome was that the measured load-displacement and energy absorption levels were similar.

MODEL COMPARISON

*Results shown for machined bracket with improved spot-weld







Recent recalibration of spot-weld models has resulted in excellent correlation with experiment for all three configurations.

SUMMARY

- Simple material substitution of UHSS material for a 590 MPa strength steel proved inadequate. Geometric changes such as fold initiators and modifications to the cross-section/flange geometry were required, but did enable significant weight reduction.
- One less major component to form, 6 less spot-welds to assemble.
  Laser weld within TWB exhibited good performance (no evident cracking).
- Early experiments revealed need to mitigate spot-weld unzipping through re-design of front bracket attachment and spot-weld process optimization.
- Improved 1.0/1.2 mm Ductibor® 1000-AS hot stamped crush tip demonstrated successful folding response with spot-weld failures confined to within consolidated folds.
- Loads in final hot stamped crush tip were slightly lower than in baseline production model, suggesting that down-gauging was overly-aggressive – need to revisit gauge selection.
- Most recent CAE models with refined spot-weld calibrations accurately captured response for both folding and unzipping cases.

OUTLOOK

- Further optimization to establish final weight reduction potential warranted
  - Continued topology and fold initiator optimization using Superfolding Element Analysis Techniques
- Weld strength optimization will continue to be a requirement at these high parent metal strength levels
- Consider Usibor® 2000-AS in the S-rail section.
- Consider more crash test configurations than just the US-NCAP Full Width Rigid Barrier front crash test (shallow offset, oblique, side).

Ductibor® 1000-AS axial crush rails with (right) and without (left) advanced fold initiator design using Superfolding Element Analysis Techniques

FOR MORE INFORMATION

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