GREAT DESIGNS IN STEEL

Multi-Cell UHSS Side Sills for Battery Electric Vehicles

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Multimatic

Scope

- Determine if multi-cell roll-form Ultra-High Strength Steel (UHSS) structures have the potential to achieve the equivalent side pole impact performance of extruded aluminum BEV sill structures at significantly lower cost with little or no mass penalty

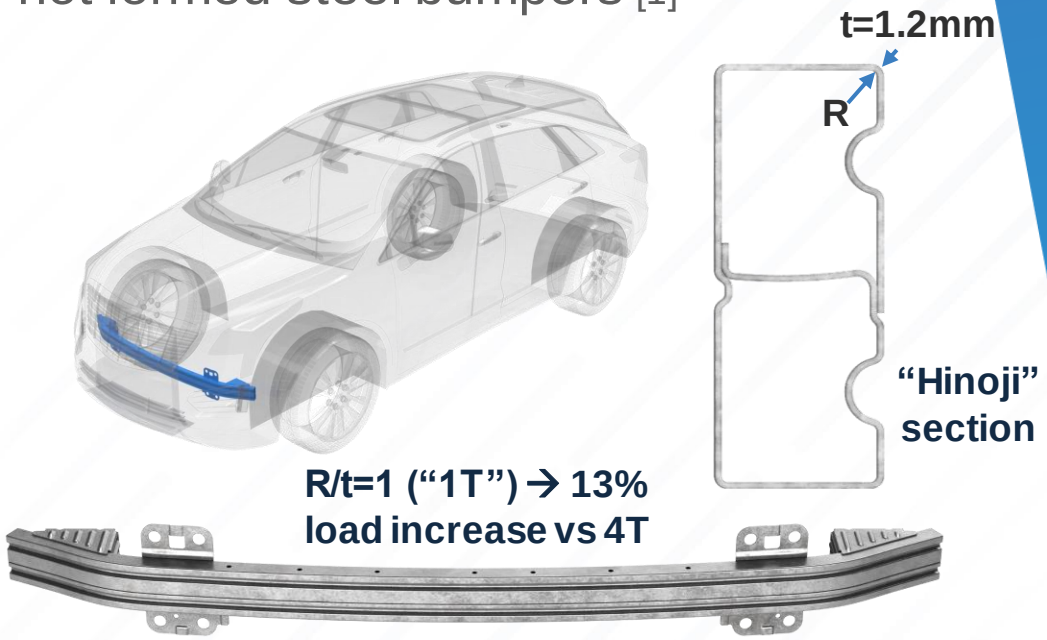
- Evaluate the effect of various UHSS roll-form structure design and material parameters on pole crush performance relative to a representative extruded aluminum sill structure

- Examine performance efficiency, defined as the relative mass of the component vs the baseline needed to absorb the same pole impact energy

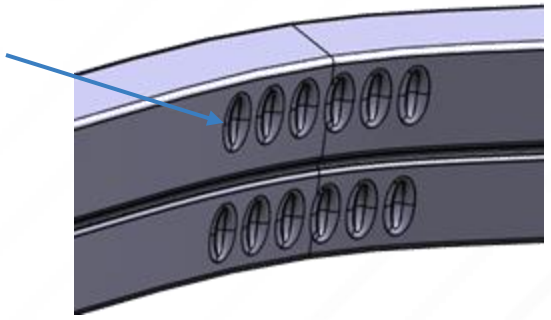
Background – Aluminum Bumper Conversion

GDIS

2023 GDIS → Converted aluminum to ACCRA® hot formed steel bumpers [1]



Integrated emboss structural countermeasures



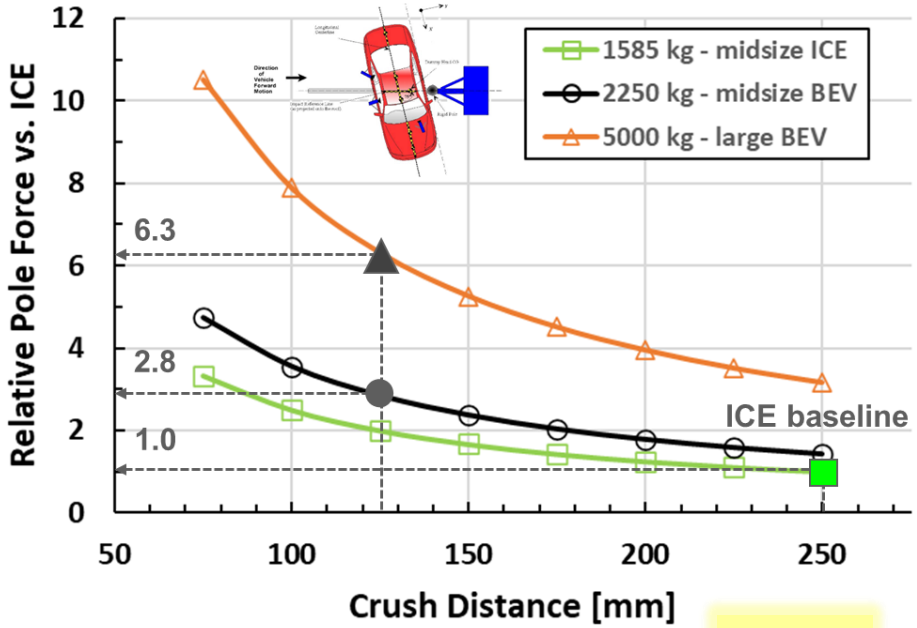
Mass Comparison (kg)			
Design:	AL	Potential Accra	Final Drop-In
Beam	3.637	3.825	3.847
Blockers (ea)	0.308	0.176	0.450
Mounting Plates (ea)	w/ beam	0	0.168
Total	4.370	4.177	5.083

Boron steel: Mechanical Properties

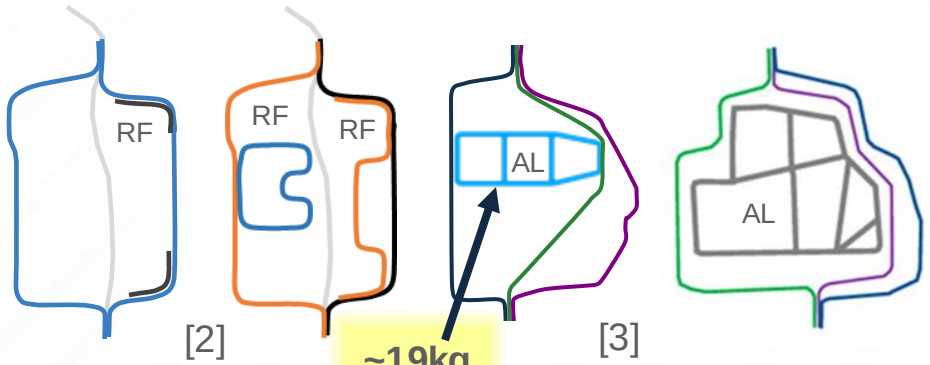
- >1100 MPa Yield Strength
- >1400 MPa Tensile Strength
- 5% Elongation

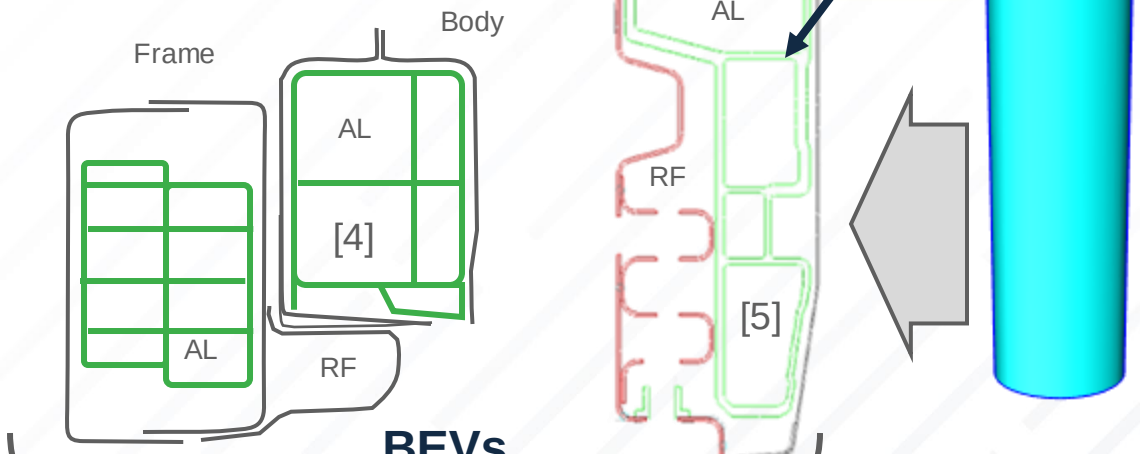
BEV Sill Constructions

- Increased BEV mass and reduced intrusion vs. ICE due to battery → significantly higher pole impact force
- Net result is a more complex and heavier side sill (rocker) structure



RF = UHSS Roll-Form AL = 6XXX Aluminum Extrusion



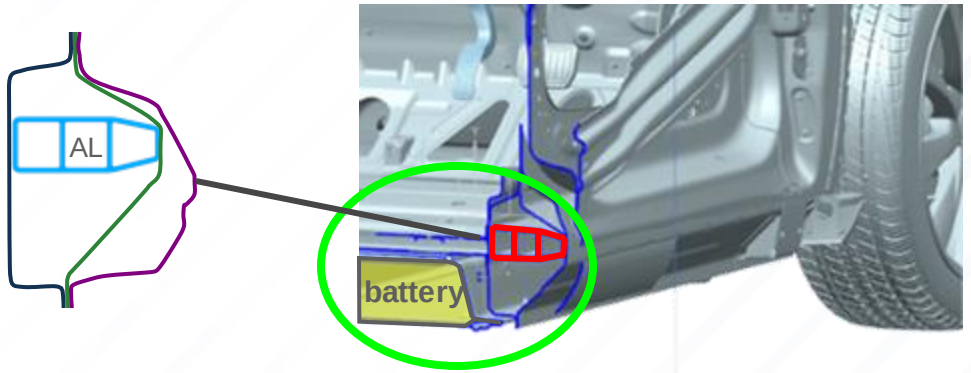


Small to mid-sized vehicles

Large vehicle

Side Sill Impact – Small/Mid-Size BEV

Analytical study to assess the potential of replacing an extruded aluminum Energy Absorber (EA) with a UHSS alternative to reduce cost and improve vehicle assembly



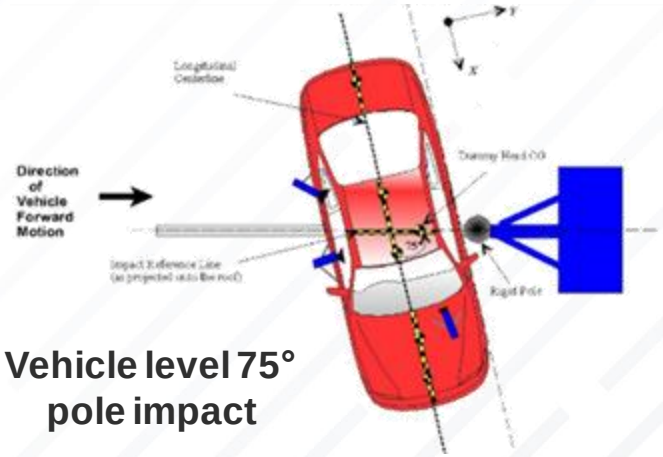
Baseline

- 3 cell 6XXX aluminum extrusion (representative of mid-sized SUV)

Scope

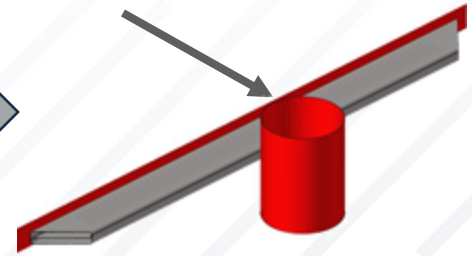
- Identify the mass potential to meet baseline pole energy absorption performance within same component package space
- Evaluate a range of UHSS materials for a 2-cell “Hinoji” roll-formed section
- Evaluate effect of strategic embossing on crush efficiency

AL extrusion **UHSS roll-form**



Vehicle level 75° pole impact

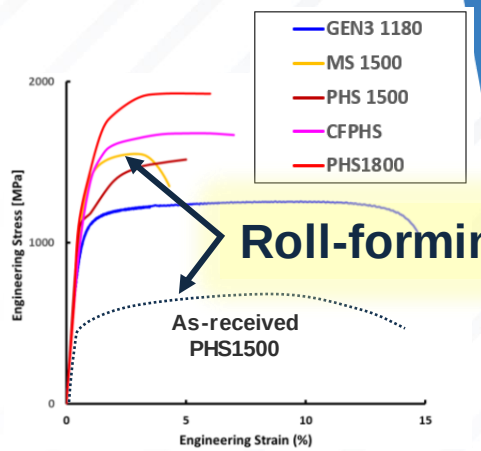
Component level 75° pole impact

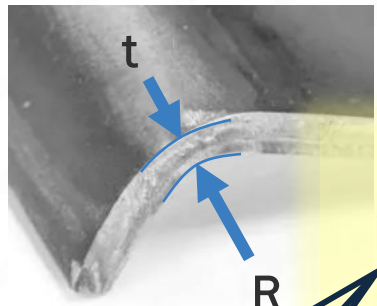


UHSS Roll-Forming Considerations

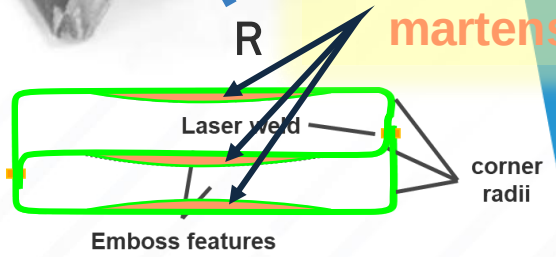
Material Grade	Min R/t	Emboss?	Post Hot forming	Weld HAZ*	Comments
Gen 3 1180	1-2	Yes	N/A	Reduced	Spring back
MS 1500	2½-4	No	N/A	Yes	Flatness
PHS 1500	~1	Yes	Yes	No	
PHS 1800 / CFPHS	~1	Yes	Yes	No	

*Heat Affected Zone



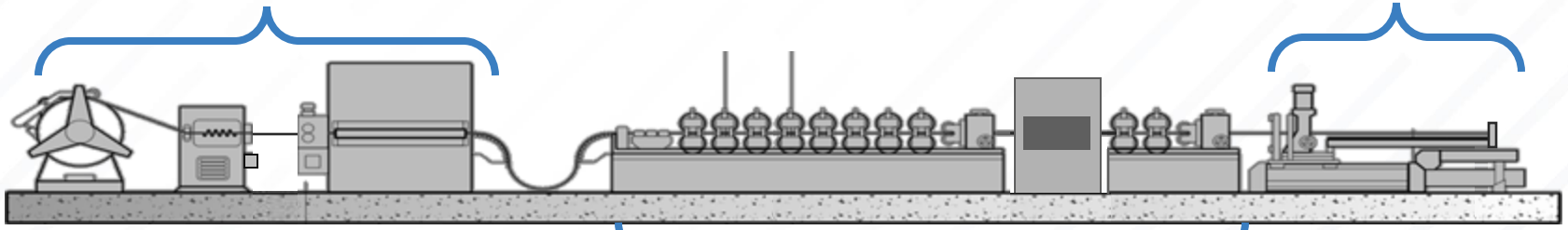


Emboss not possible with martensite



Un-coiler, flattener, feeder, pre-pierce/pre-form

Cut-off Operation



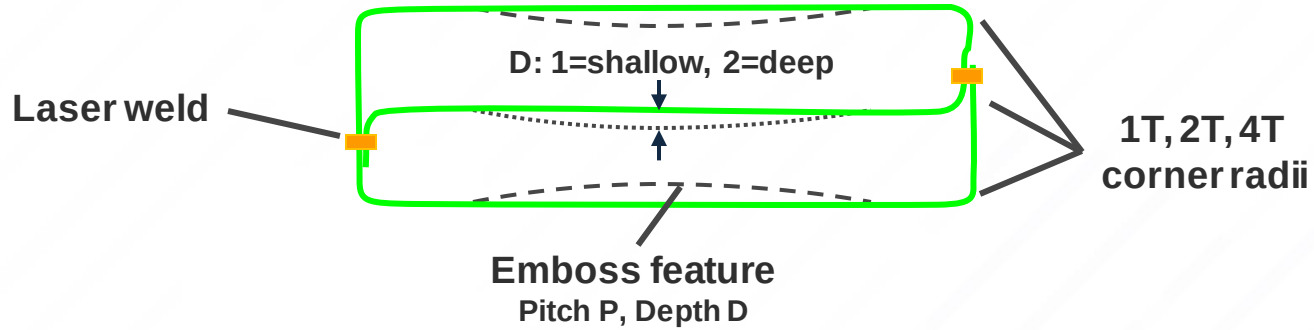
Entry guide, roll-former, in-line welder, straightener/sweep fixture

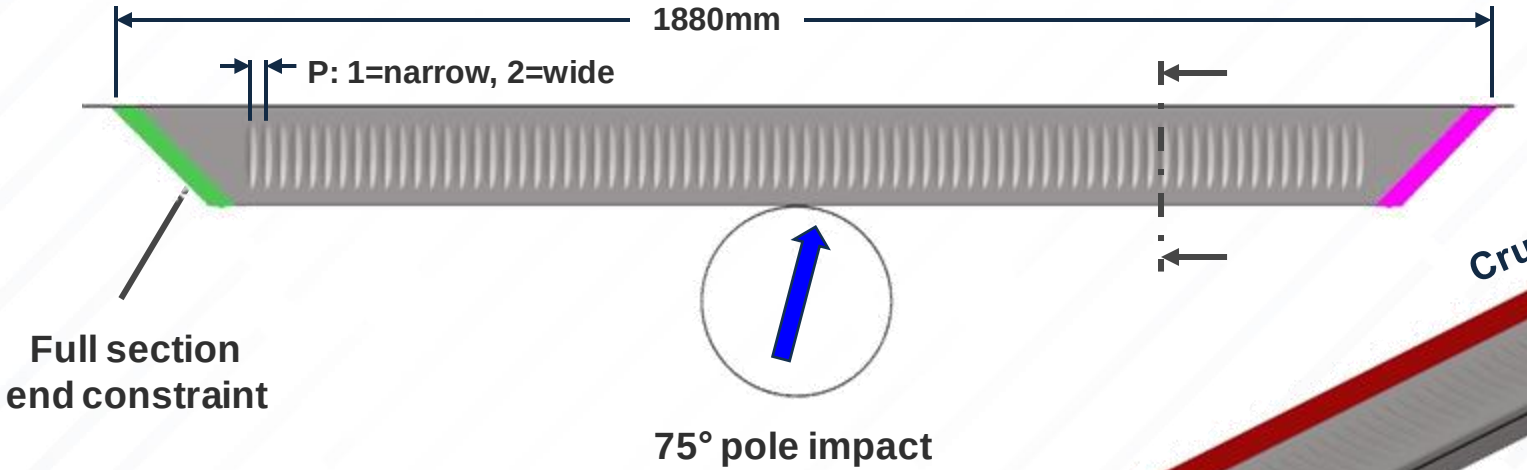
Component Level FEA Model

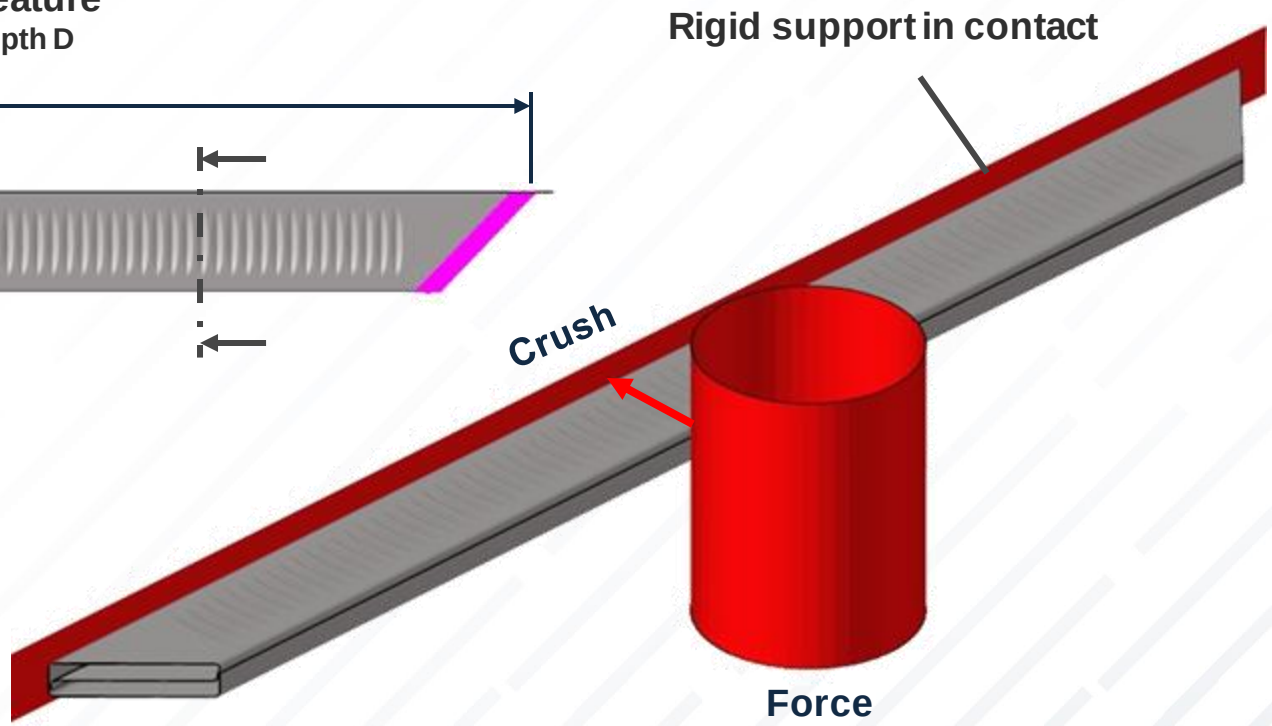
Representative UHSS materials
(material failure included)

- Gen 3 1180
- PHS 1500 / Martensite 1500
- PHS 1800 / CFPHS

42.5 x 133.0 mm UHSS roll-form section
@ 1.6mm material thickness

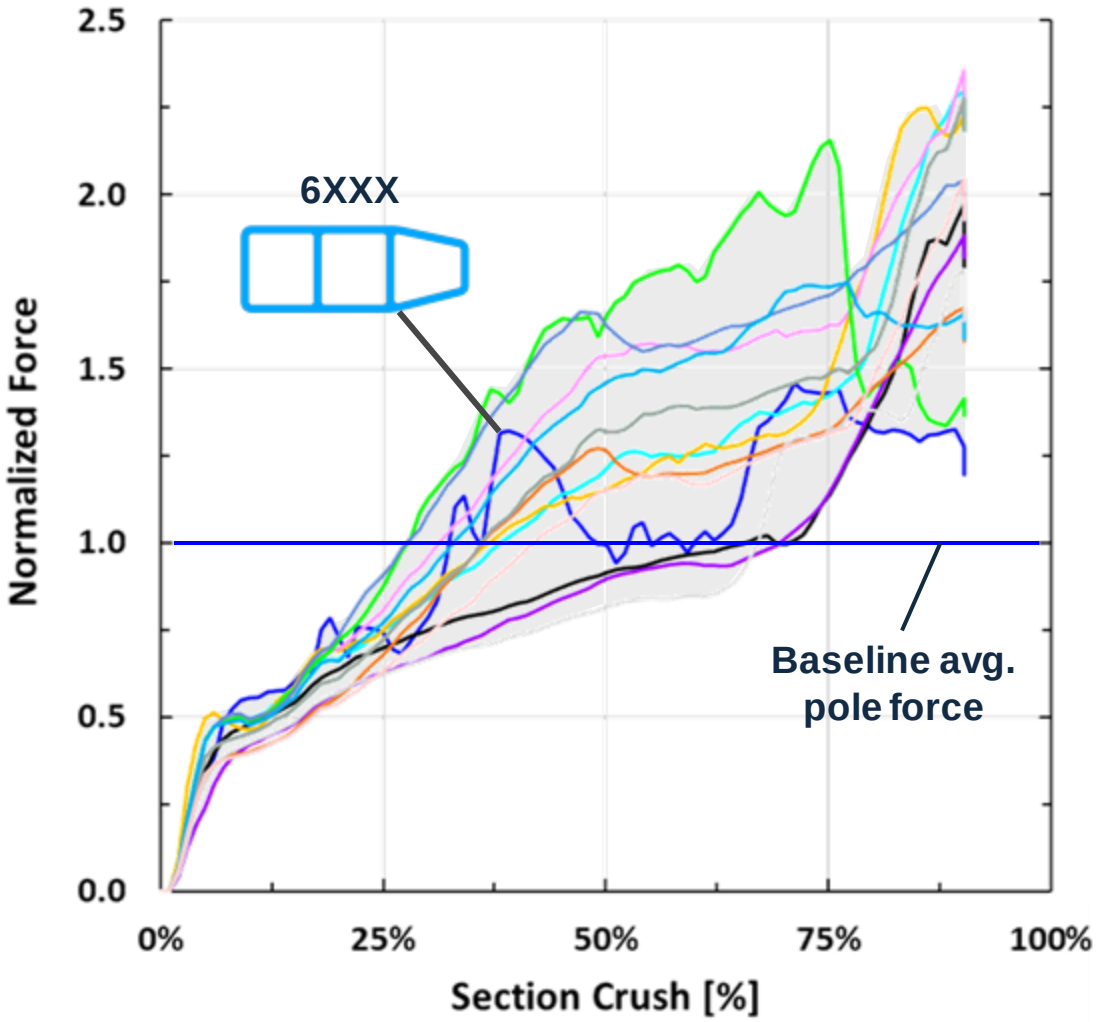


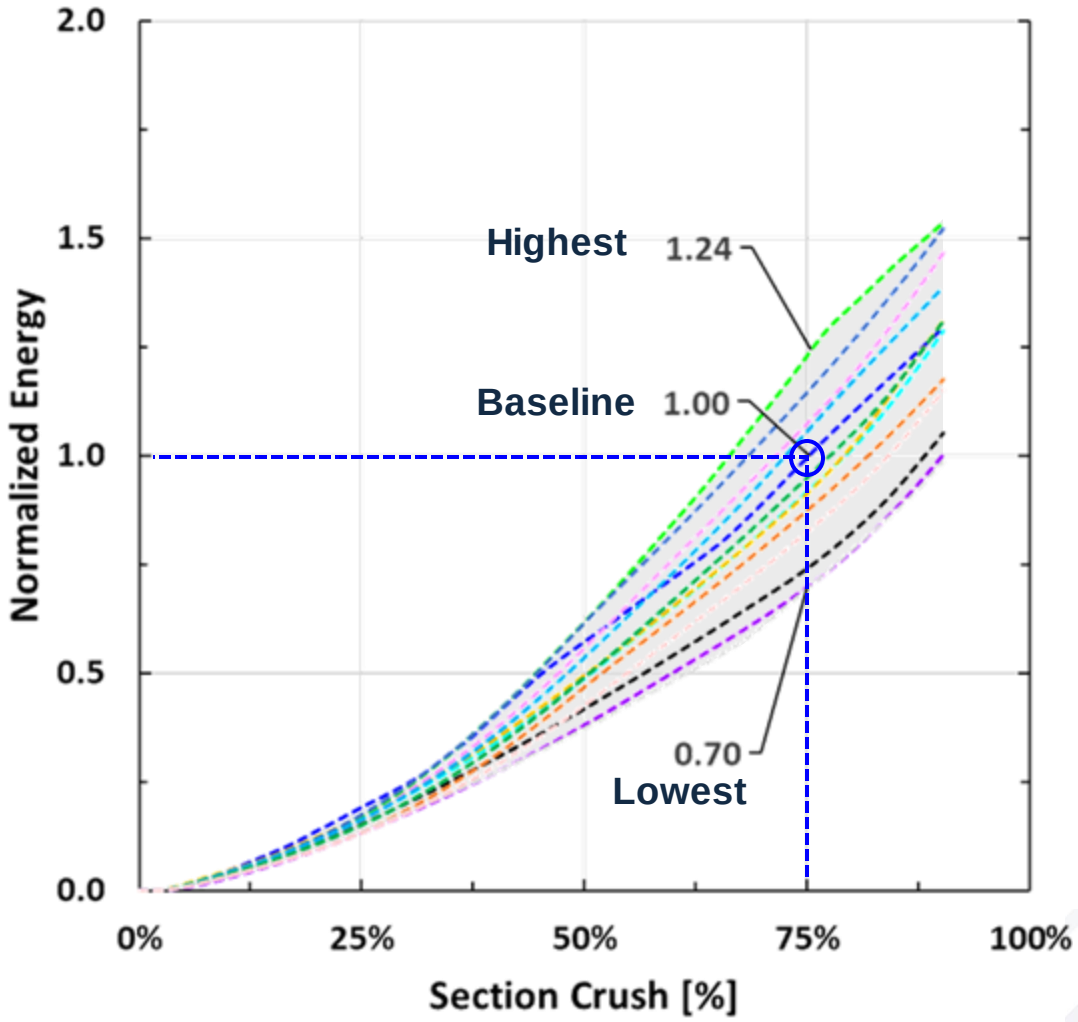




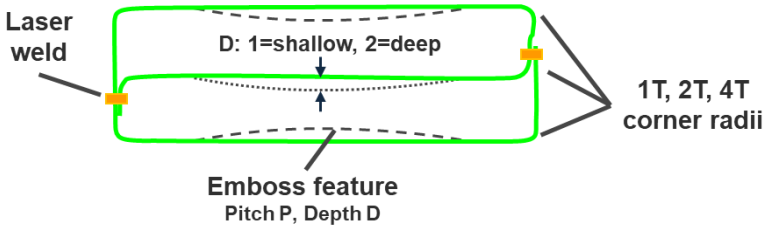
Results Summary

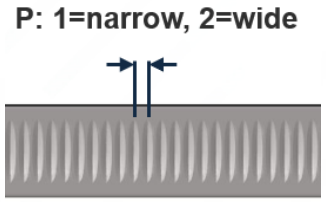
- **Normalized force** = pole force normalized by average baseline pole force
- **Normalized energy** = energy/mass normalized by baseline energy/mass @ 75% section crush

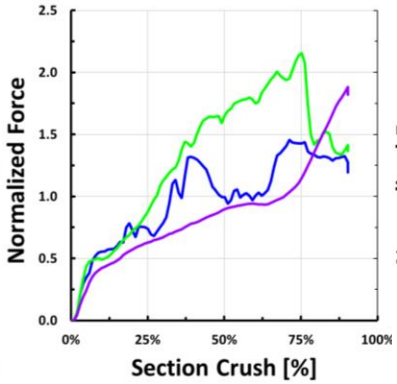


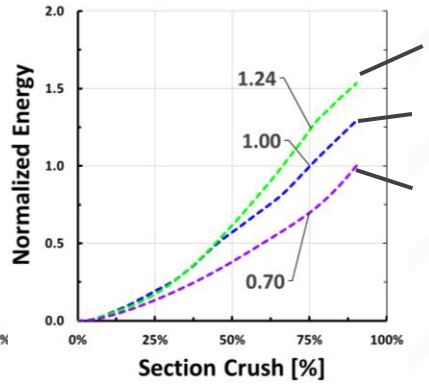


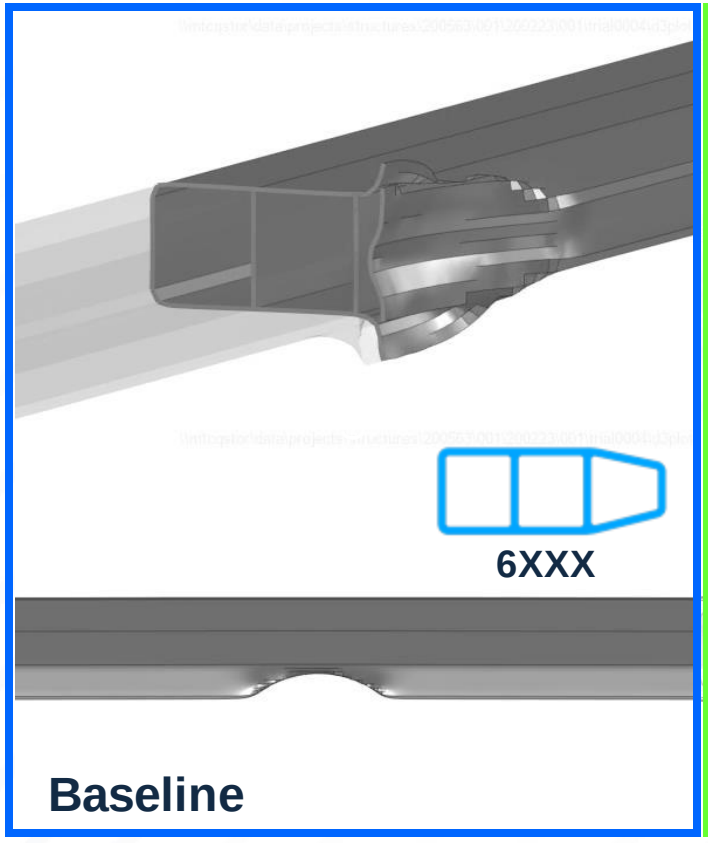
Deformation Mode Comparison

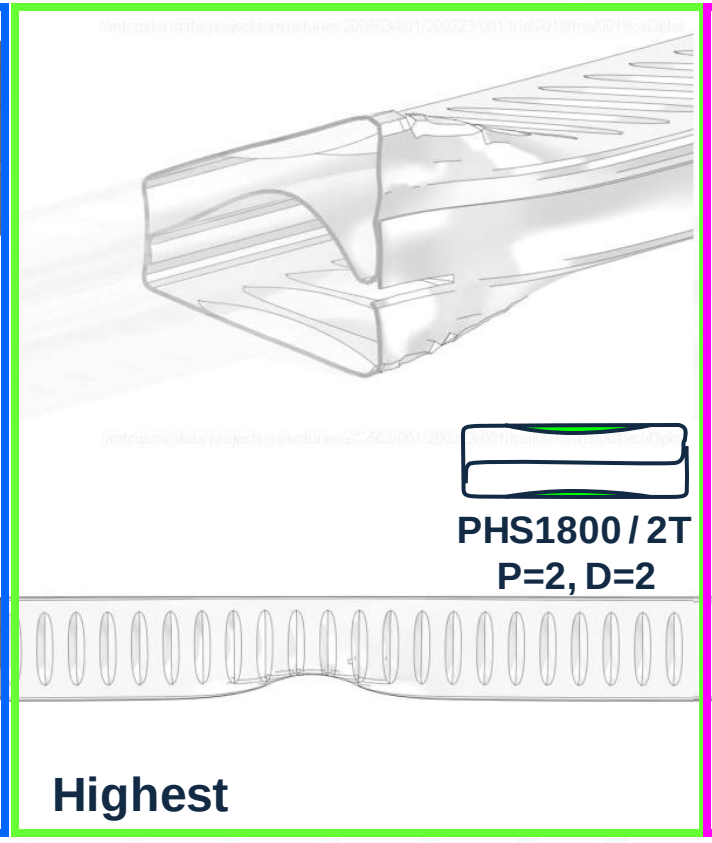


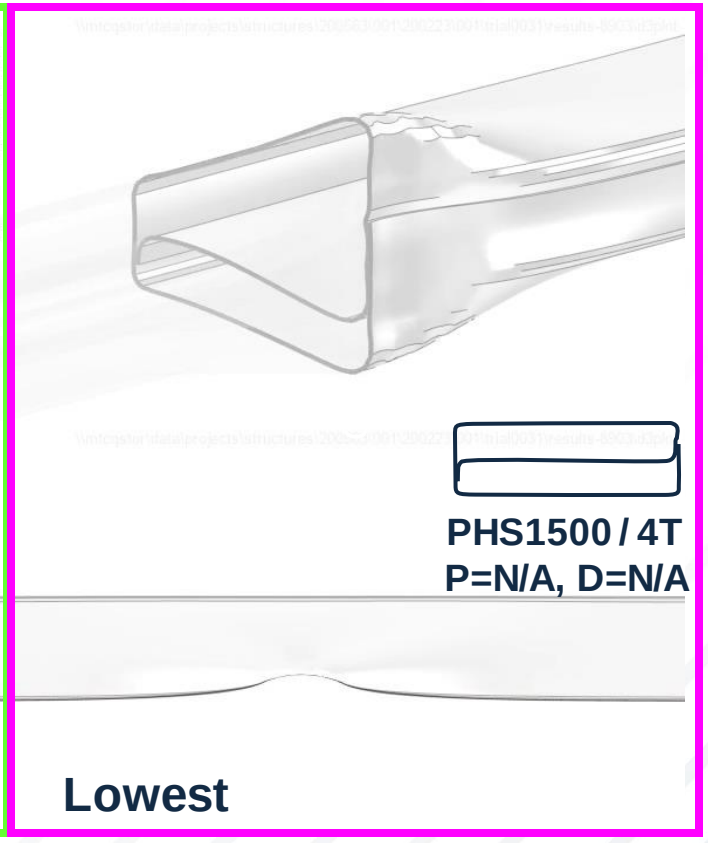






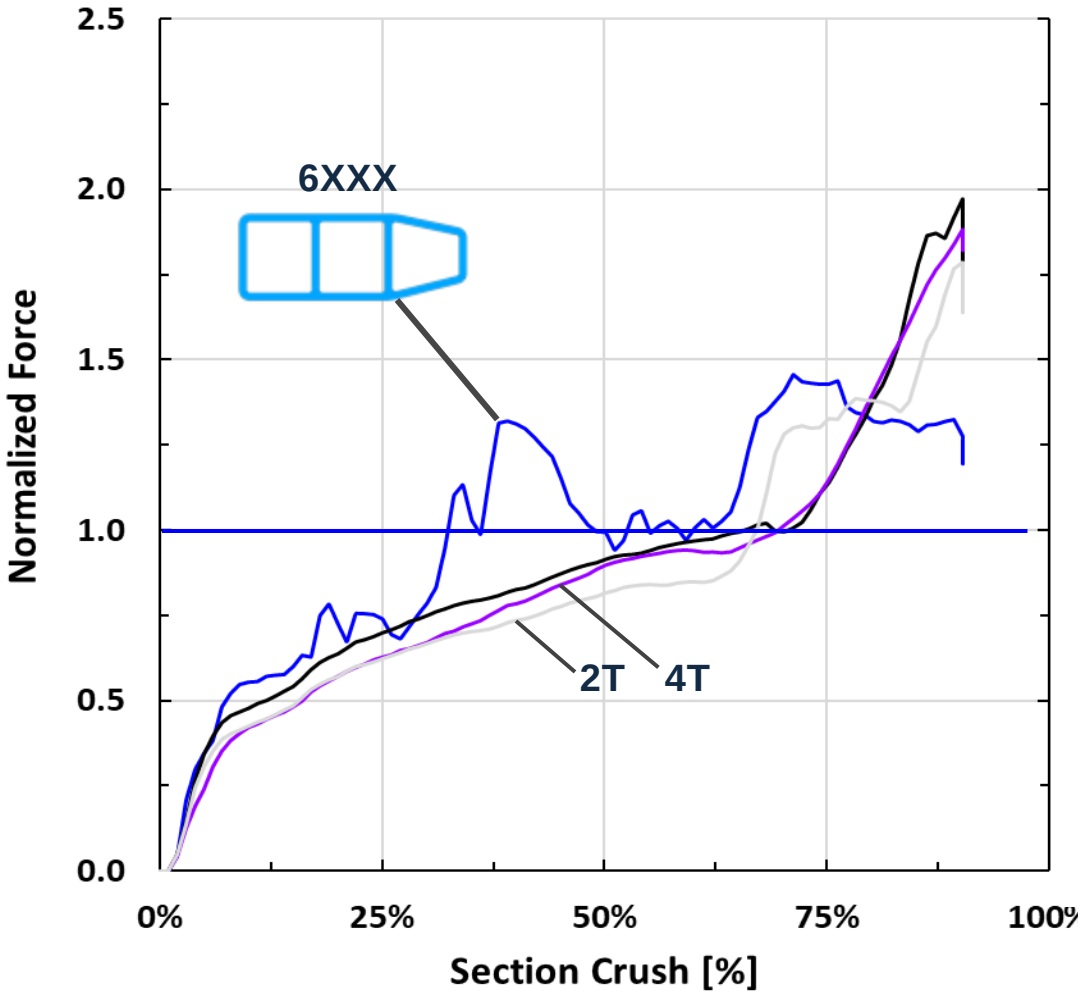


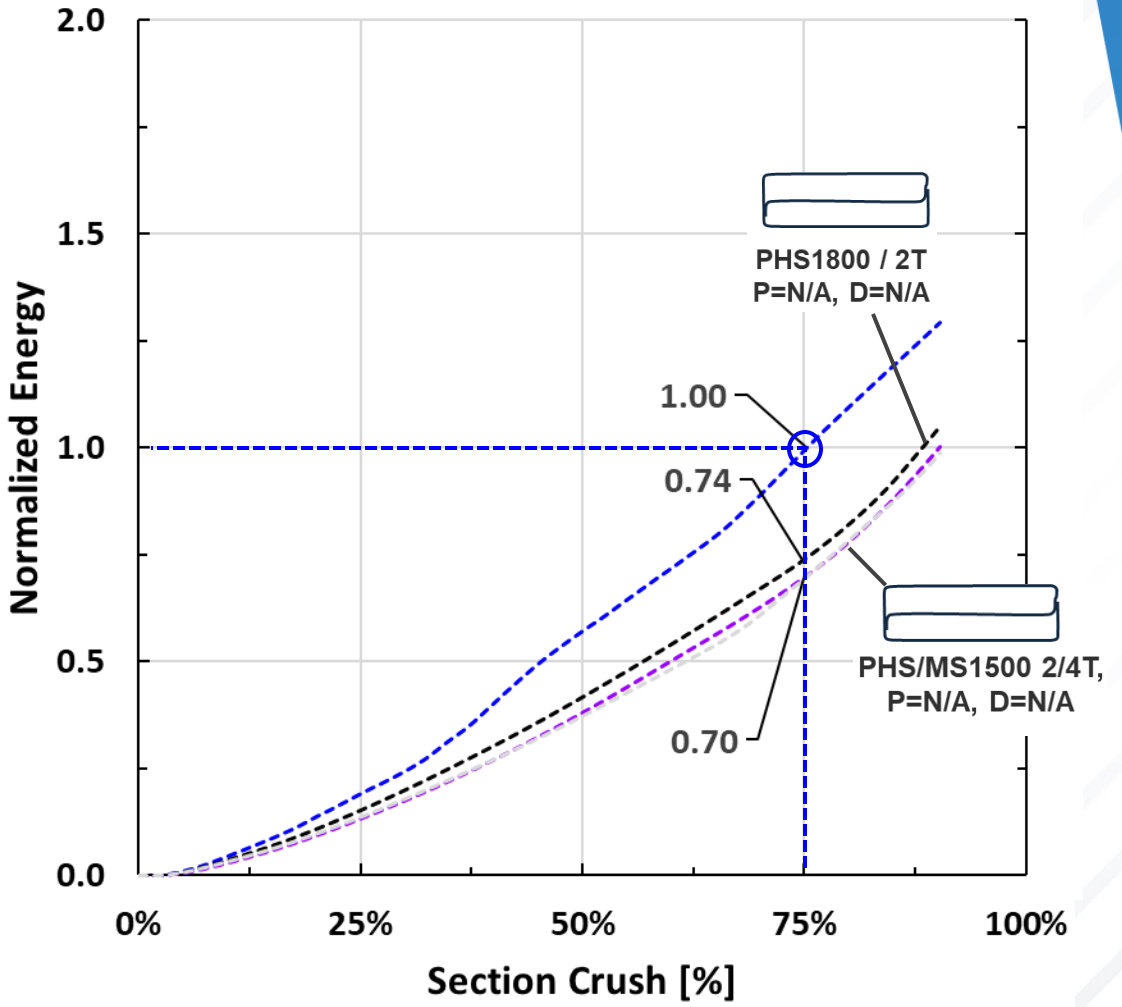




Martensitic Roll-Form

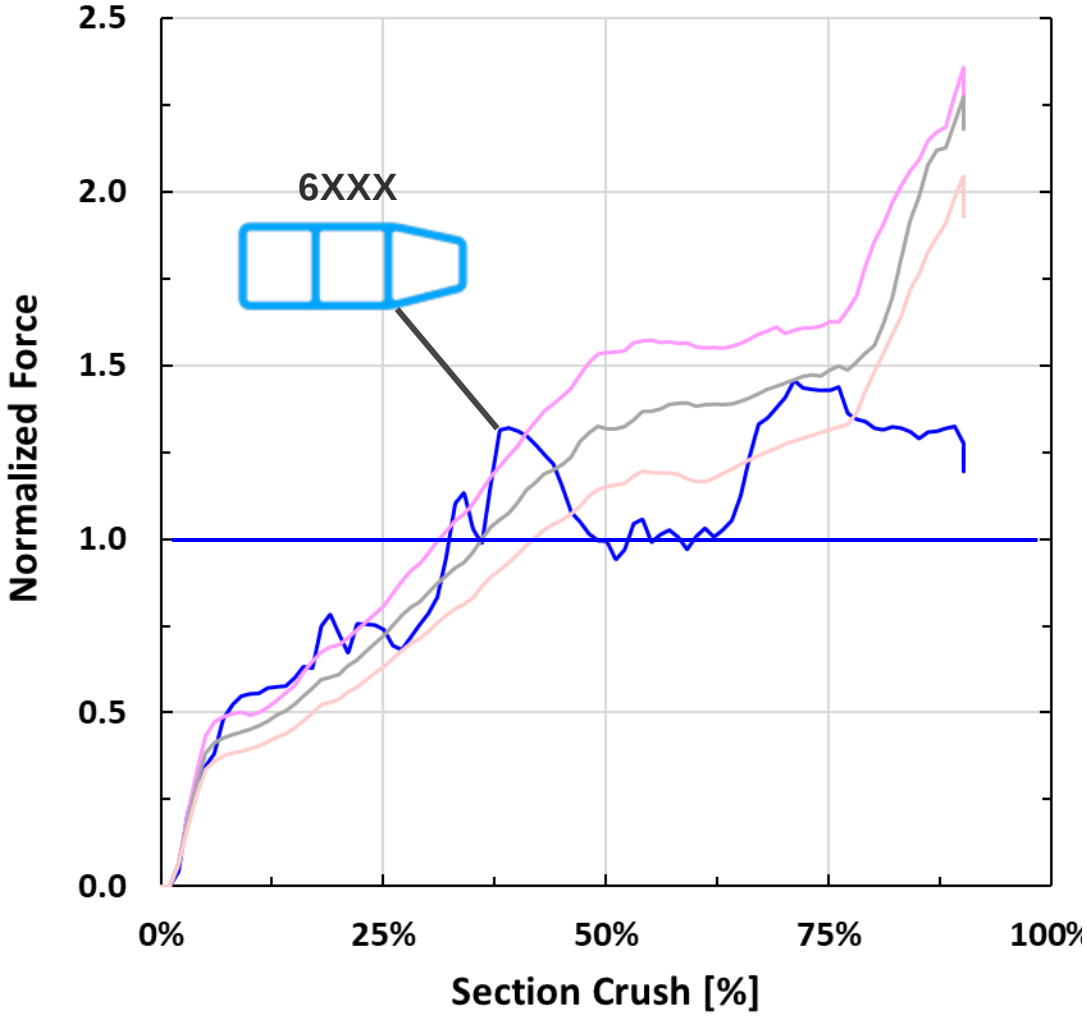
- PHS(MS)1500/1800 roll-form (NO emboss) → 26-30% less efficient

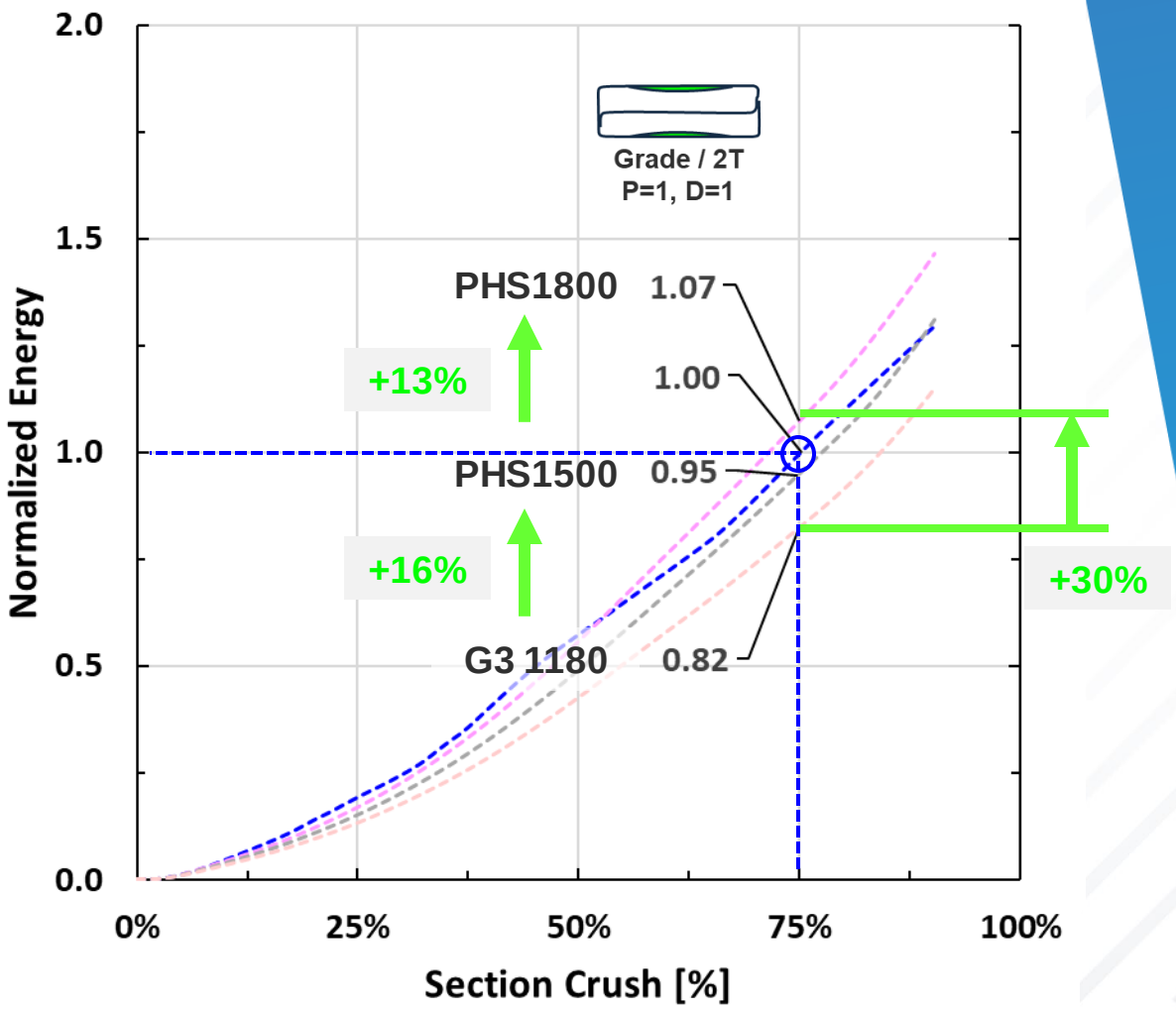




UHSS Grade (G3 1180 / PHS 1500 / 1800)

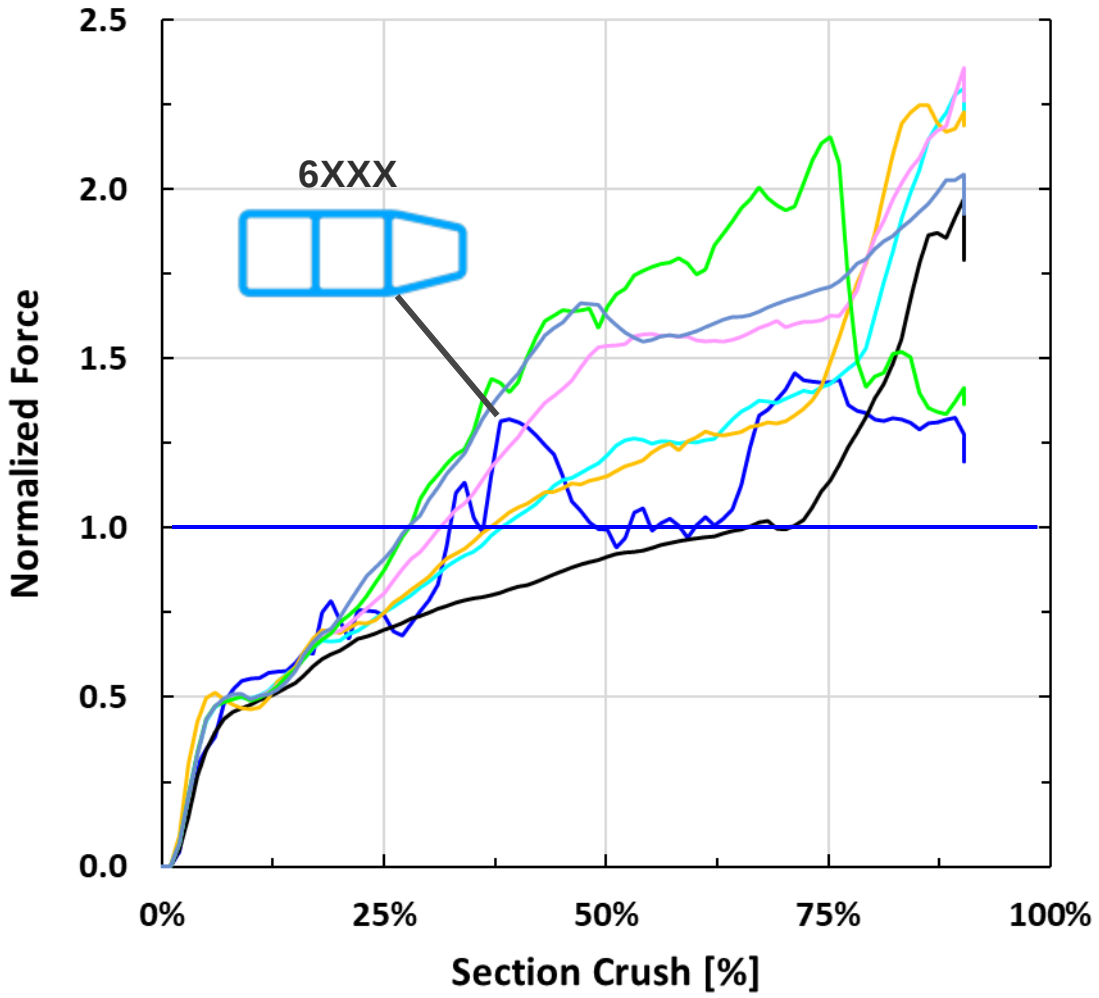
- PHS1800 (2T, w/ emboss P=1, D=1) → 18% less to 7% more efficient

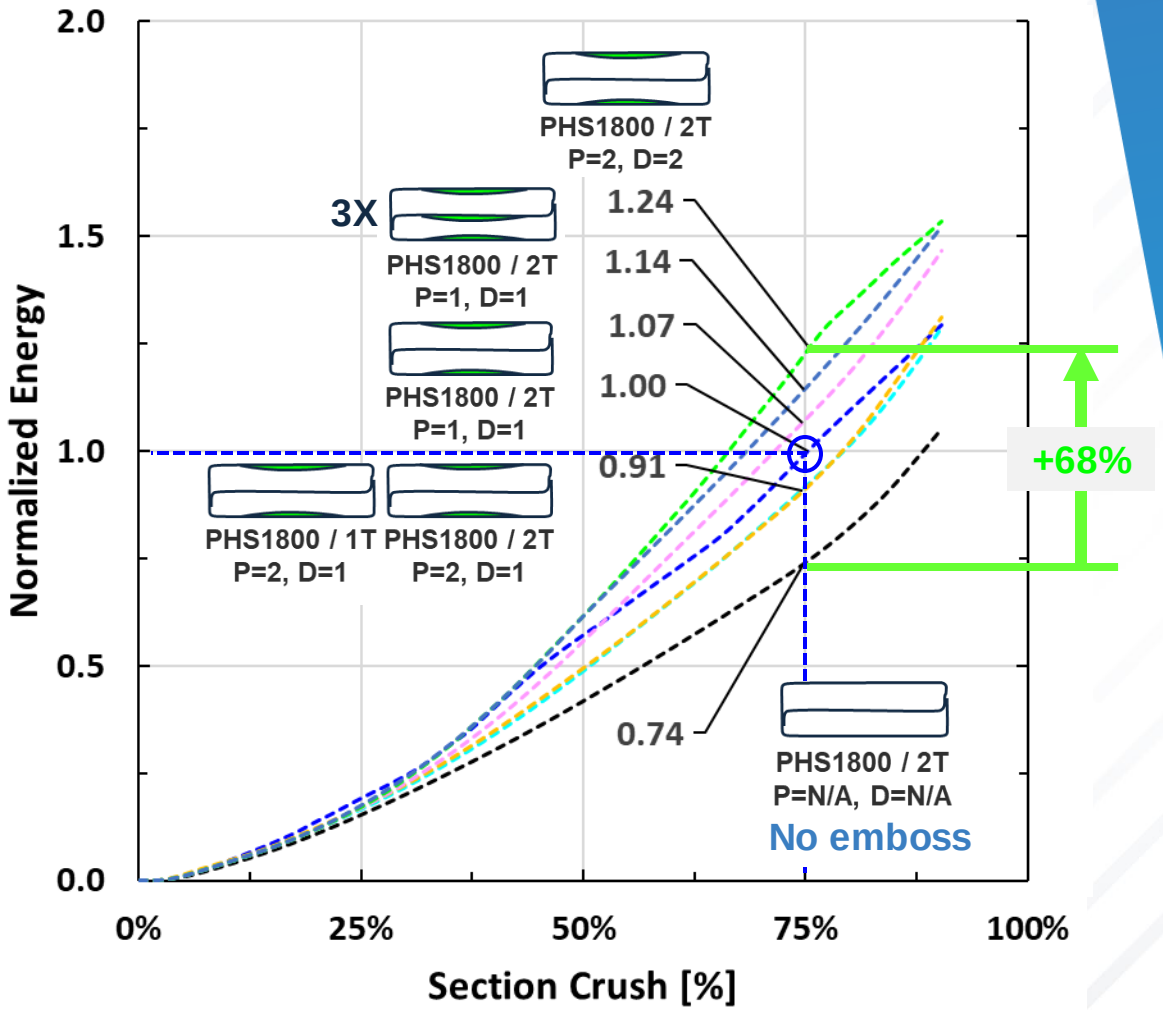




Emboss Geometry (PHS1800)

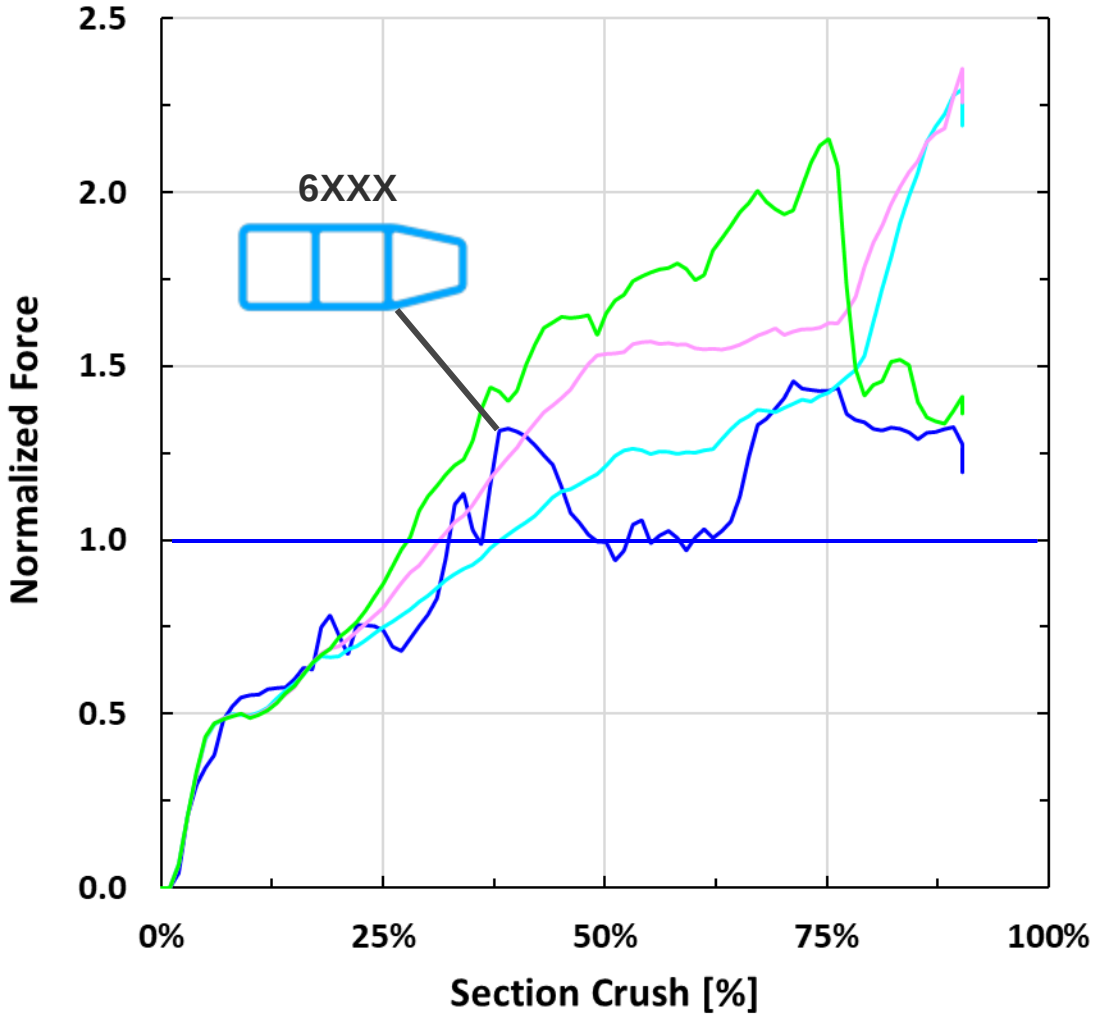
- PHS1800 w/ emboss → 9% less to 24% more efficient

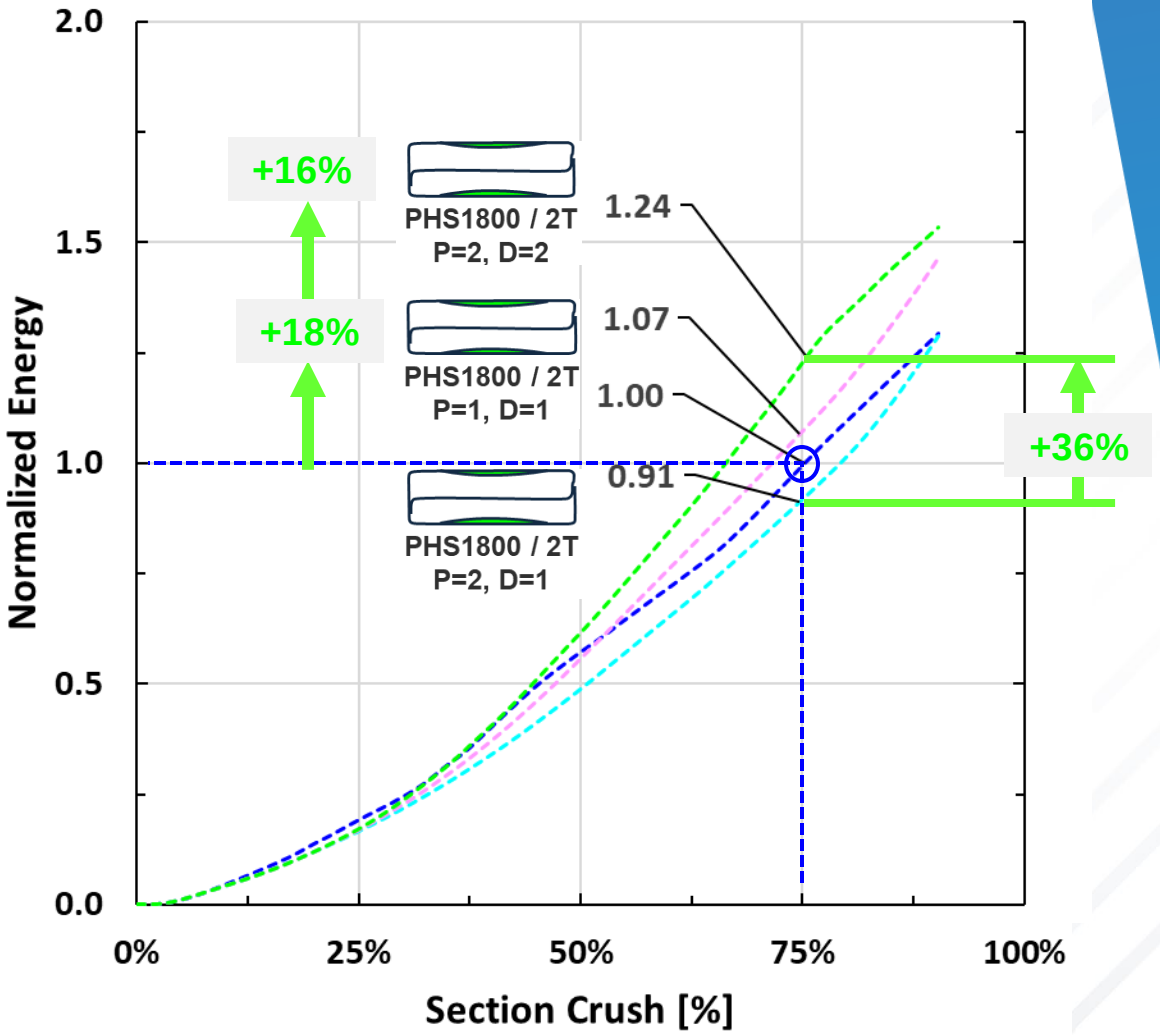




Emboss Pitch & Depth (PHS1800)

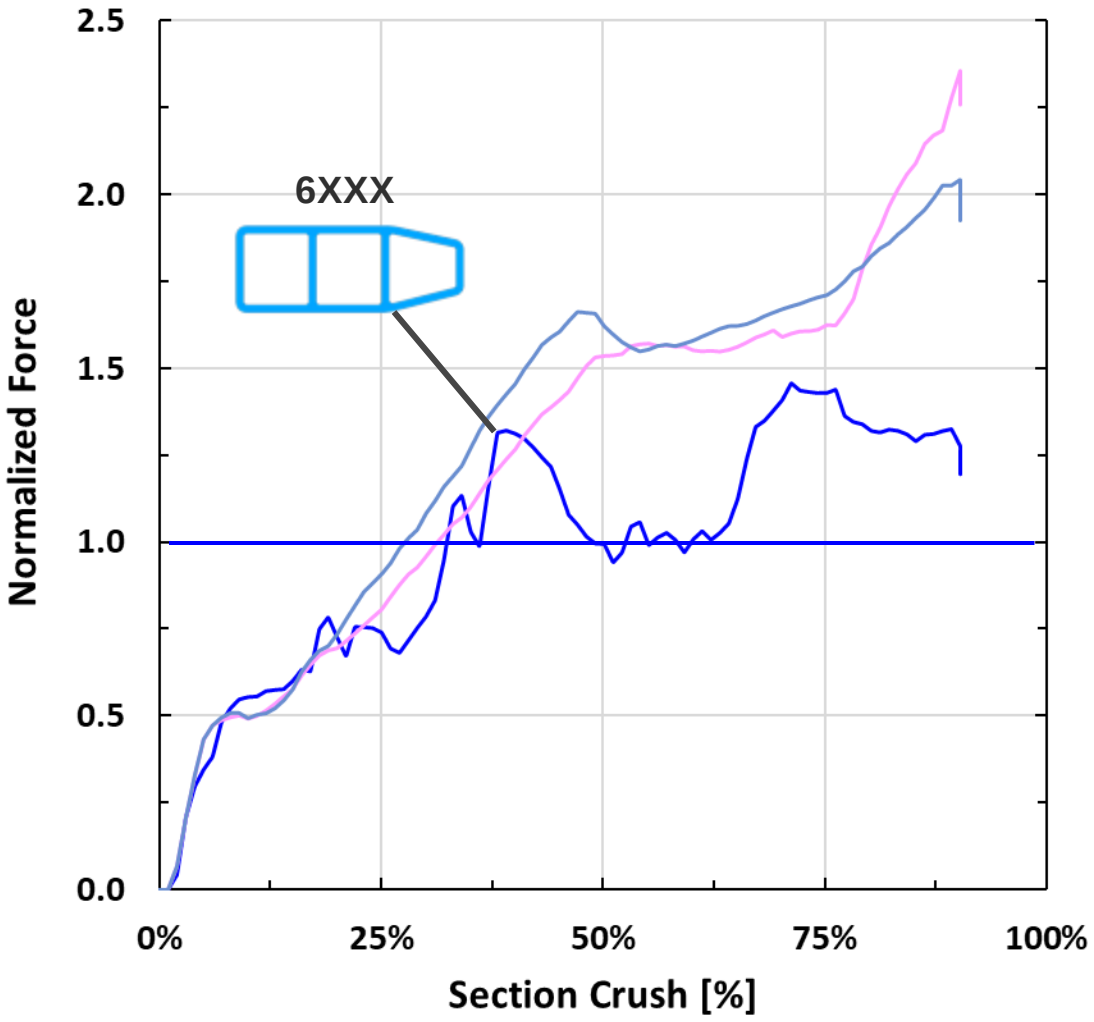
- PHS1800 w/ emboss → 9% less to 24% more efficient

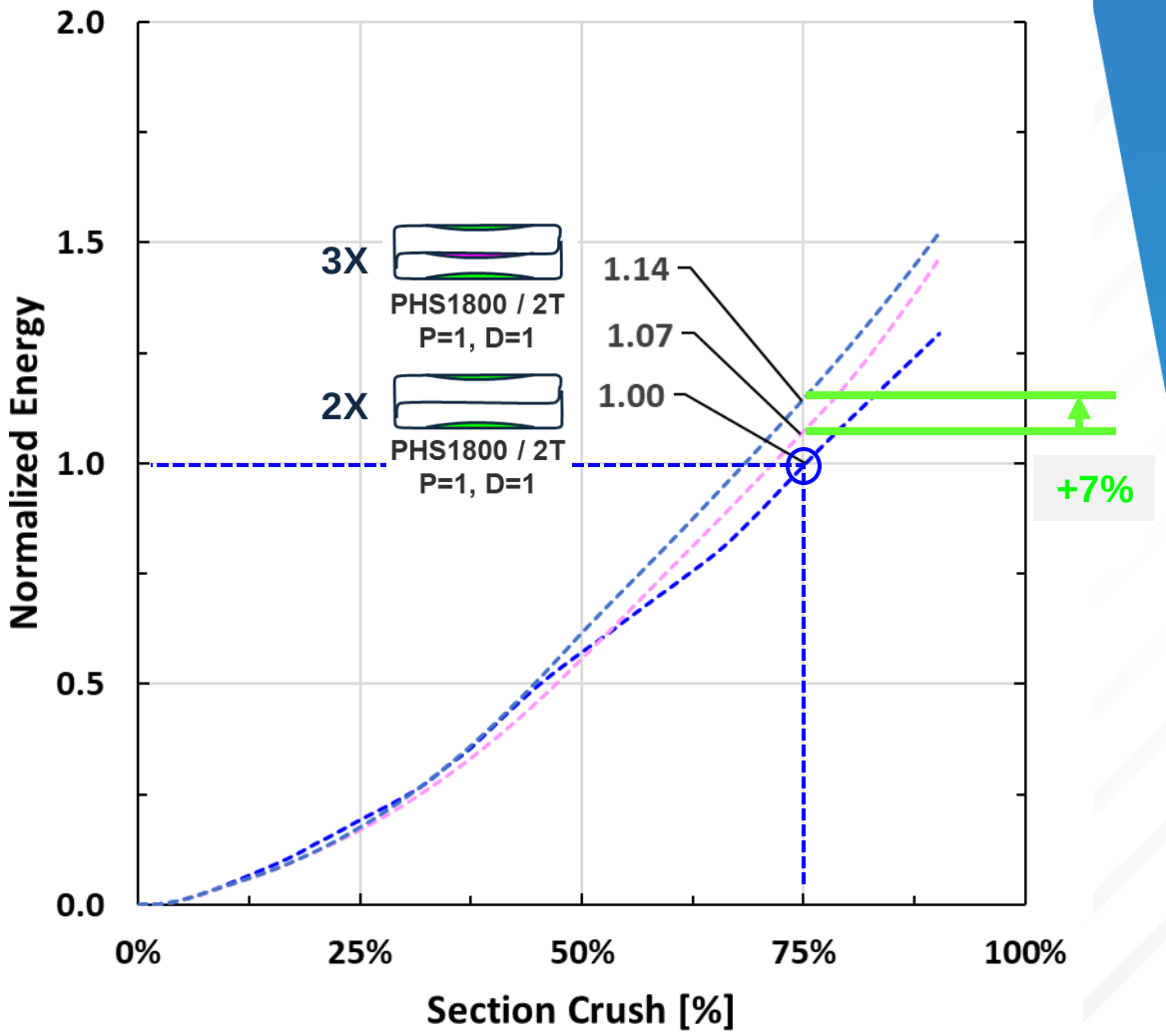




Emboss 2X vs. 3X (PHS1800)

- PHS1800 3 vs. 2 embossed surfaces → 7% to 14% more efficient



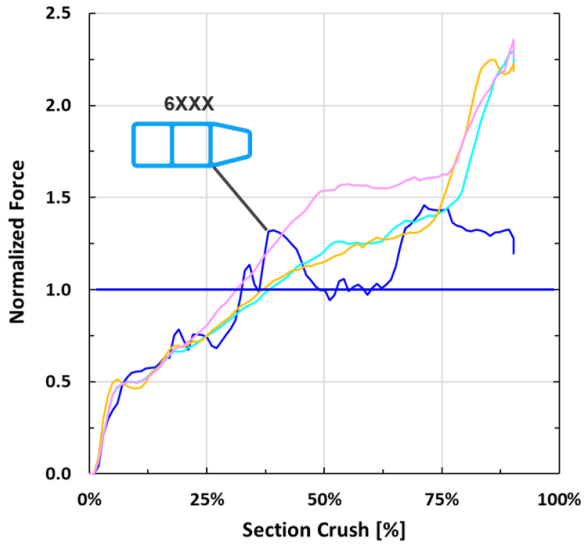


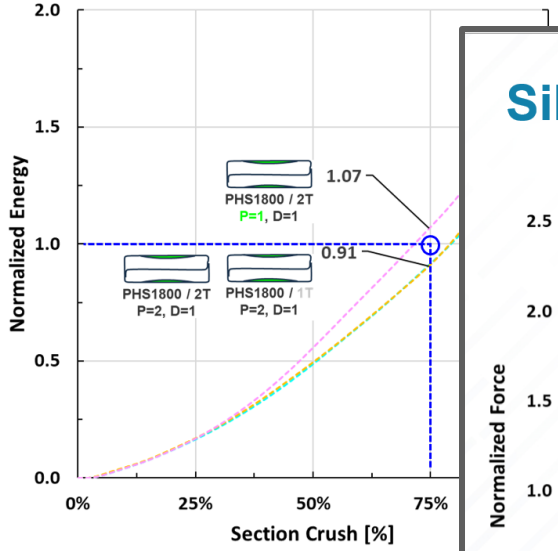
Less Significant

- Corner bend radii (section aspect ratio) and sill end conditions (part length)

Roll-Form Corner Radii (PHS1800)

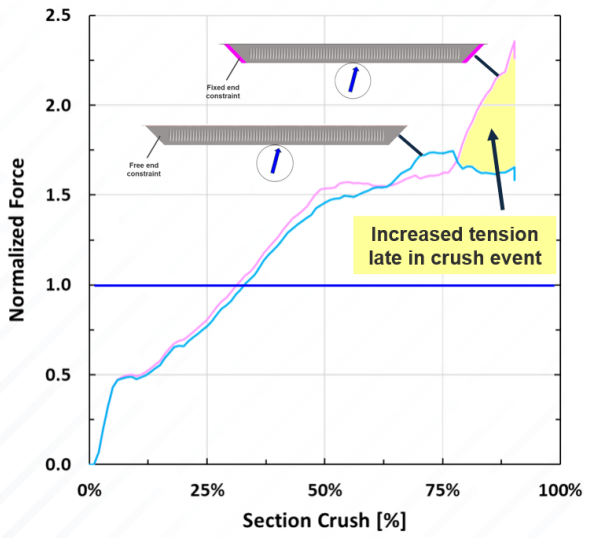
- PHS1800 (P=2, D=1) → 1T vs 2T minor effect, emboss pitch larger effect

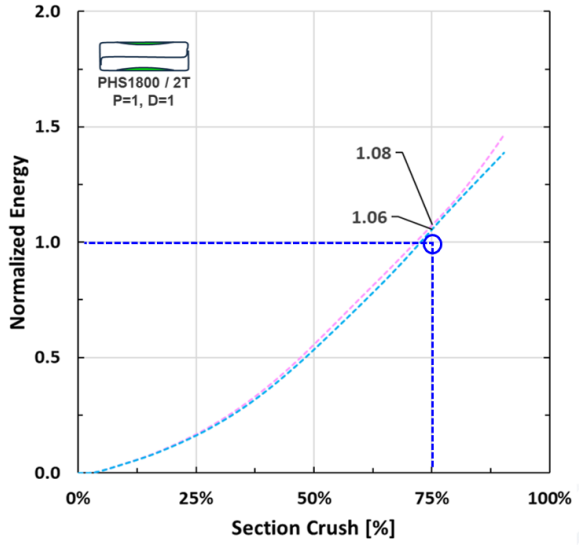




Sill Fixed vs. Free End Conditions

- PHS1800 (P=1, D=1) → end constraints only minor effect for component test





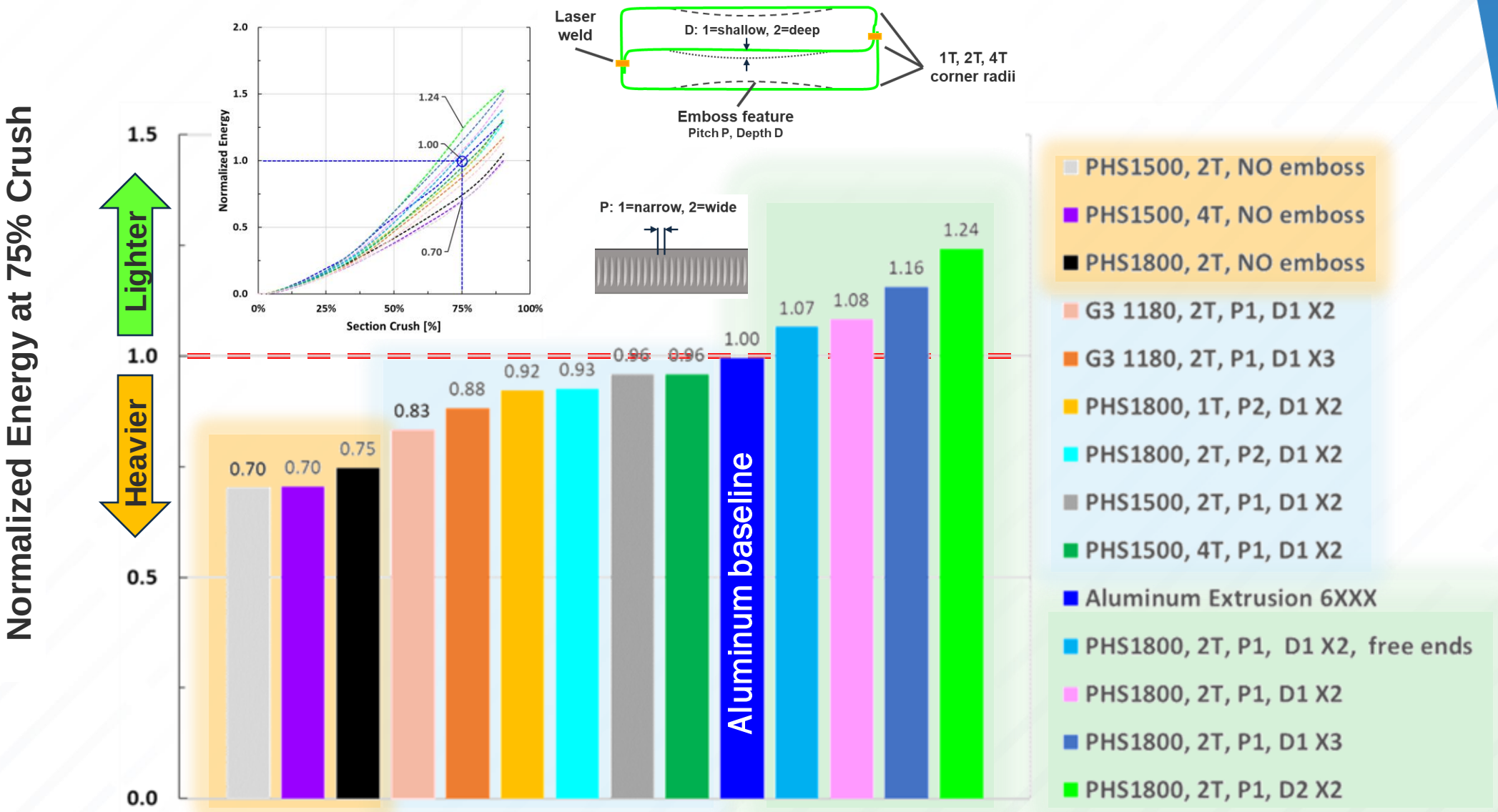
R/t is a key factor for bumper performance (aspect ratio!)

1T vs 4T → 13% load increase

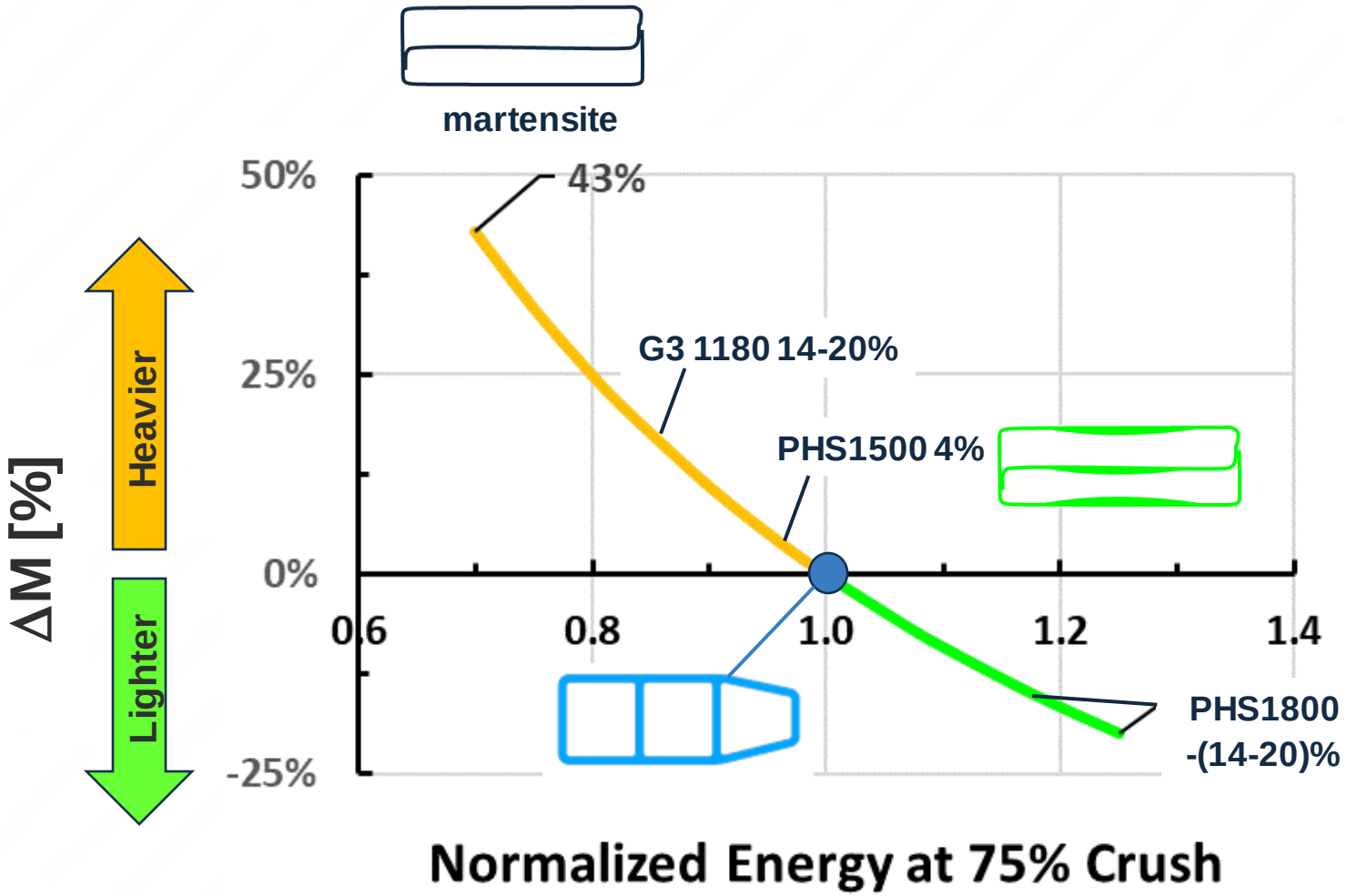
Bumper

Efficiency Summary

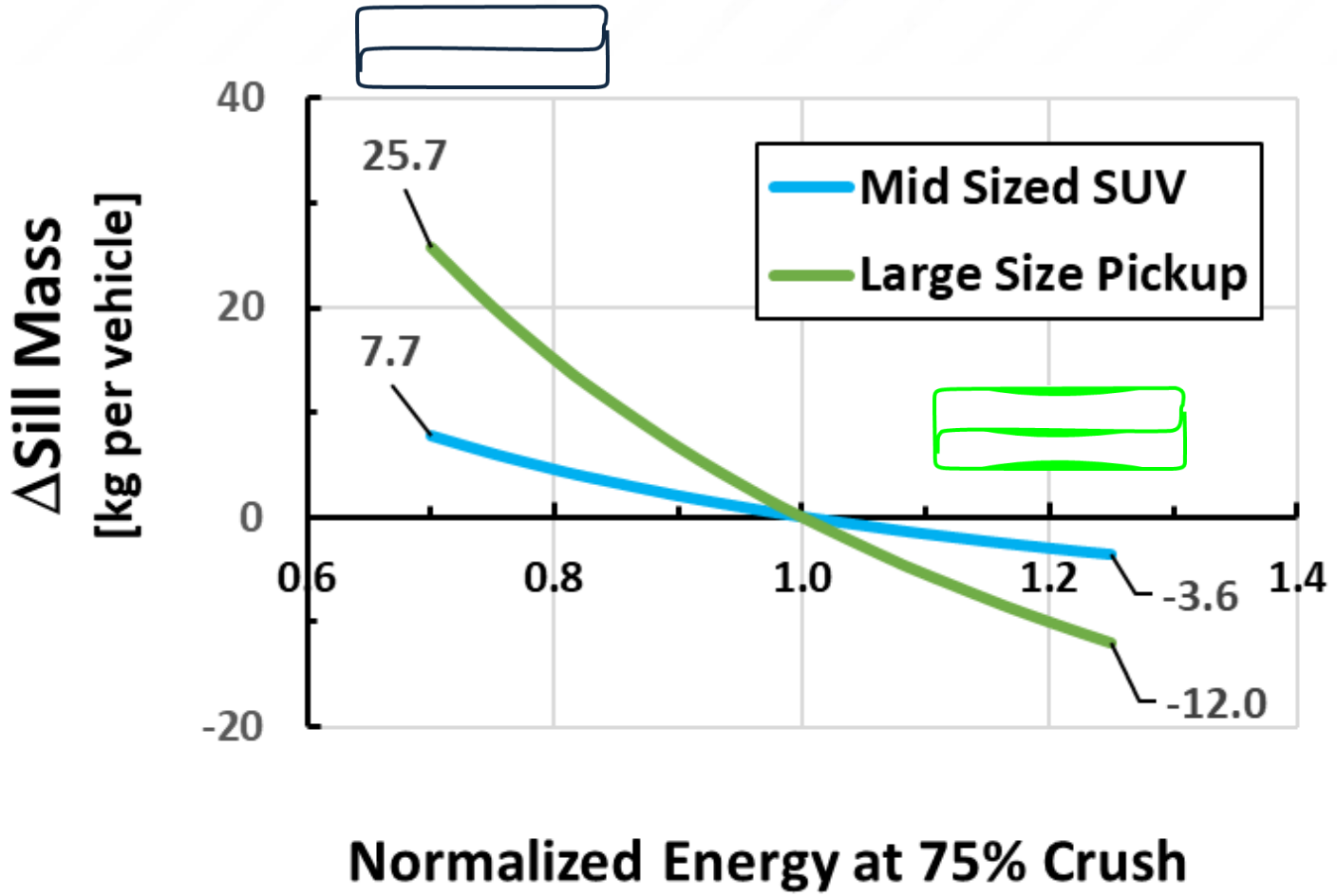
- **Normalized energy** = energy/mass normalized by baseline energy/mass @ 75% section crush



Δ Mass Summary

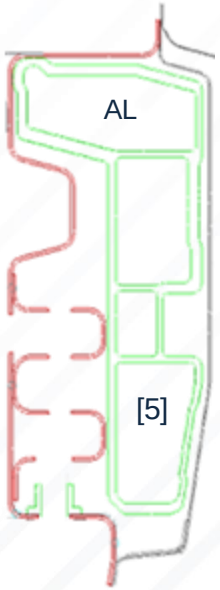


Δ Mass Summary – Vehicle Examples



Mid-sized BEV SUV

~19kg / veh

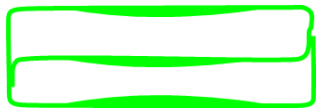


Large BEV pickup

~60kg / veh

Manufacturing Considerations

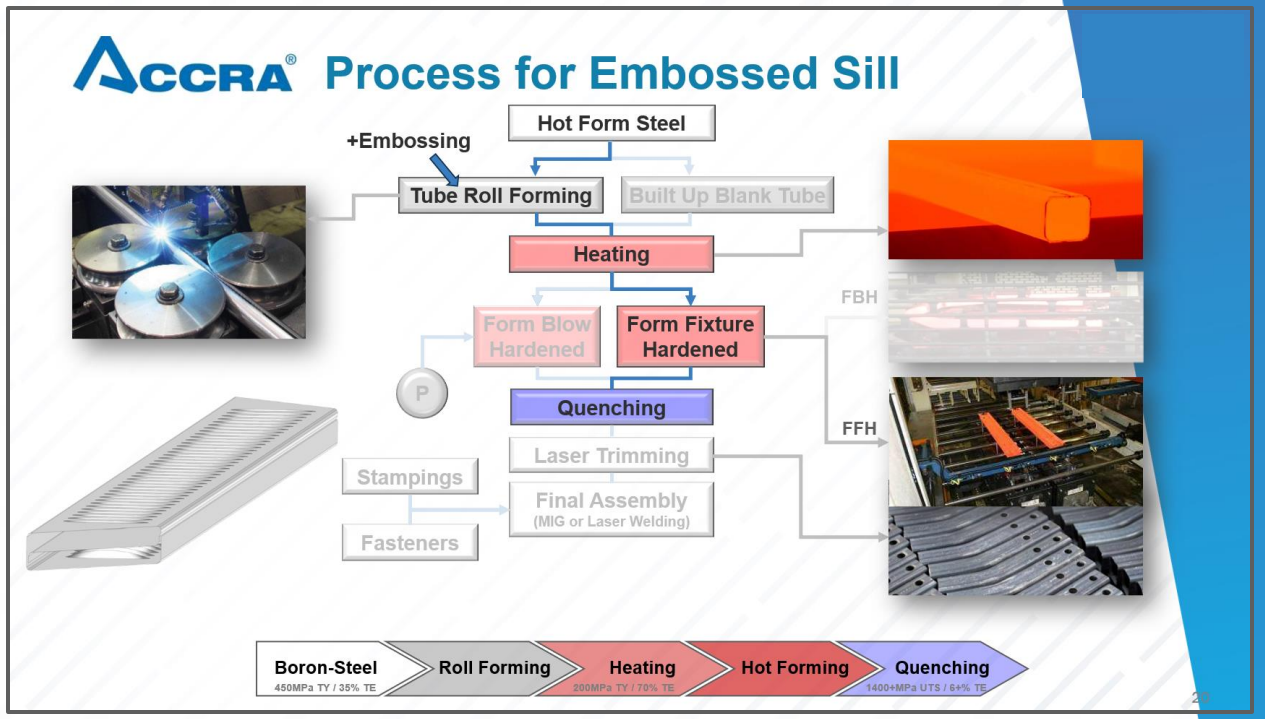
- Efficient PHS1500 and PHS1800 grade steel roll-form sections with embosses can be manufactured using the ACCRA® **F**orm **F**ixture **H**ardened process

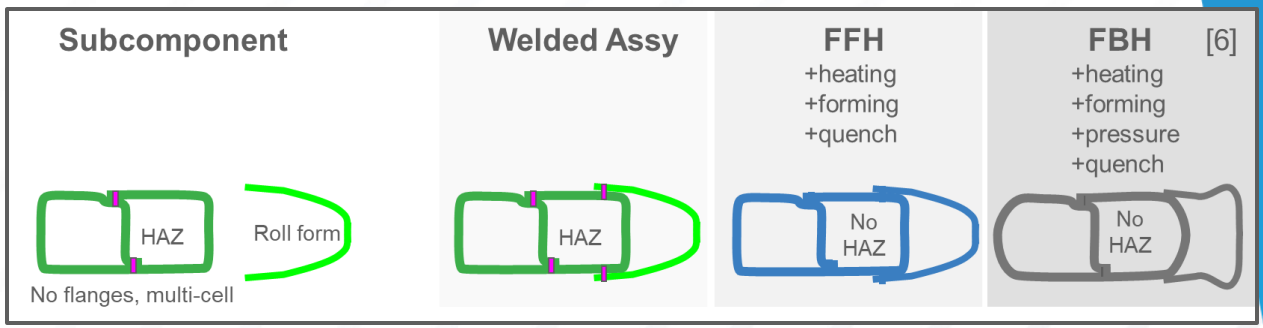


F_{peak} ~ 350-550kN

- More complex sill structures can be built-up to achieve even higher load levels for large size SUVs and pickup trucks using the ACCRA® **FFH** or **F**orm **B**low **H**ardened process

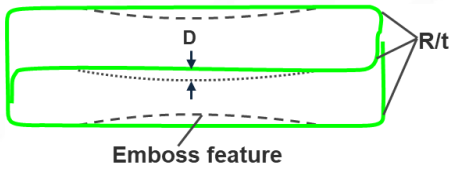
F_{peak} >> 550kN

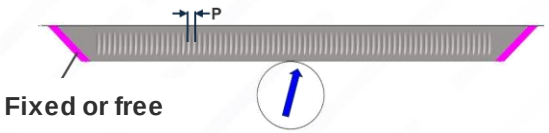


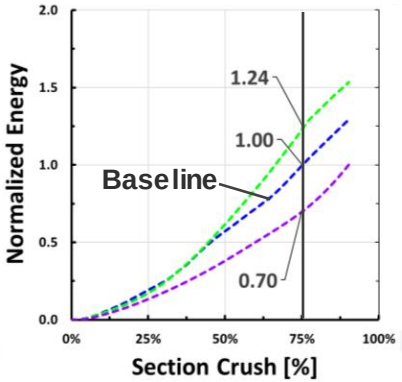


Summary

- The pole crush performance of a representative extruded aluminum sill reinforcement was evaluated using a component level pole impact FEA simulation
- The pole crush performance of a 2-cell “Hinoji” UHSS roll-form was evaluated relative to the baseline and several parameters investigated:
  - Representative material grades (Gen 3 1180, PHS/MS 1500, PHS1800/CFPHS)
  - Embossment parameters (pitch and depth, 2X/3X)
  - Corner radii (R/t)
  - Sill end conditions (fixed vs. free)
- The key performance metric evaluated is Normalized Energy at 75% section crush







Conclusions

Within the parameters of this study…

6XXX baseline

- MS1500 roll-forms are up to 30% less efficient
- Roll-forms with strategic embosses can achieve higher efficiency (ACCRA FFH)
  - PHS1500 steel grades have similar efficiency
  - PHS1800 steel grades have up to 24% higher efficiency

- Positive performance factors:
  - Higher steel grade
  - Embosses with narrow pitch and high depth
  - Embosses on all 3 horizontal web surfaces
  - Fully fixed ends, and lower R/t
- Positive impact on piece cost
  - Potential piece price reduction of 25% - 40%
  - Dependent on application specifics (size/complexity)

Acknowledgements

- Bryan Conrod, Principal Engineer, Multimatic Technical Centre
- Mark Sullivan, Vice President – Business Development, Multimatic Structures and Suspension Group
- Marco Struna, Director – Global Business Development, Multimatic Structures and Suspension Group

References

[1] Sullivan, M., Vanderbilt, E.: Hot Formed Steel Bumper Beam to Replace Aluminum, 2023 GDIS Conference, https://www.steel.org/wp-content/uploads/2023/06/Track-3-Session-7-Sullivan-Vanderbilt-Multimatic.pdf

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