GREAT DESIGNS IN STEEL

HOT STAMPING DIE DEVELOPMENT AND PROCESS SIMULATION PHS 1500 AS

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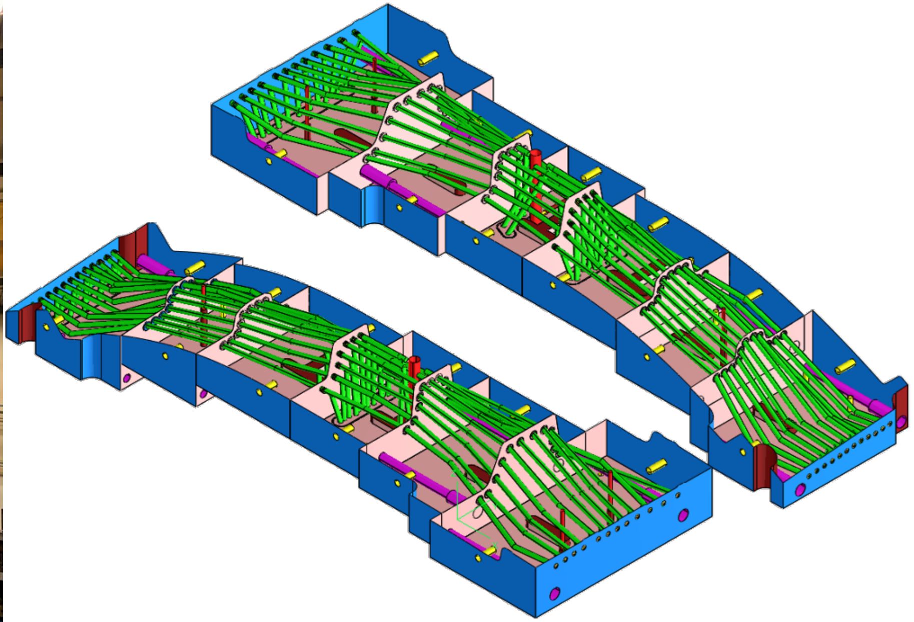
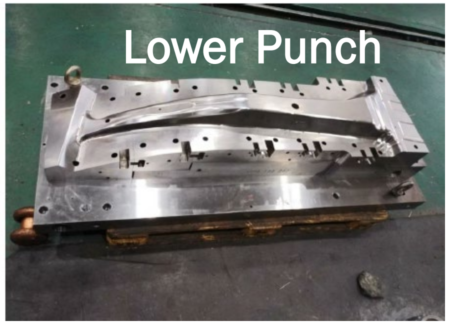
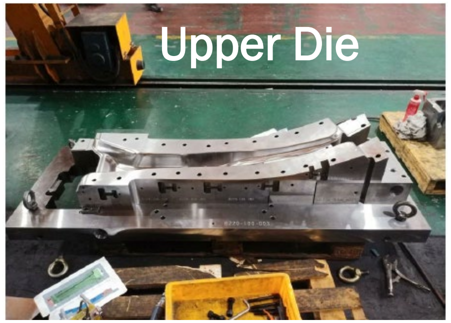
INTRODUCTION AND OBJECTIVE

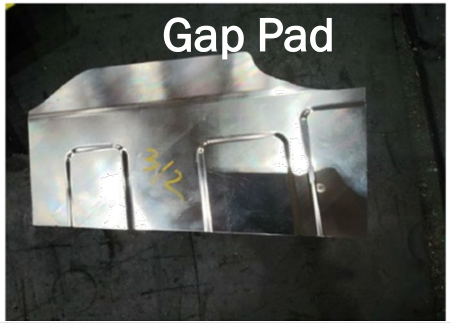
- Project objective is to study stamping conditions, and process windows for a challenging part: B - pillar.
    - Design a tool for 1.6 mm PHS 1500 AS (ATC is the industrial press tool technology partner)
    - Tool to accommodate Grades: PHS 1500 AS, PHS 2000 AS, PHS 1000 AS, PHS 500 AS, Monolithic and same-gauge LWB combinations
    - Study stamping conditions required for robust production under industrial conditions.
- Scope of this presentation – Tooling development, commissioning activities for 1.6 mm PHS 1500 AS and FEA support.

B-PILLAR / PRESS / TOOLING DEVELOPMENT



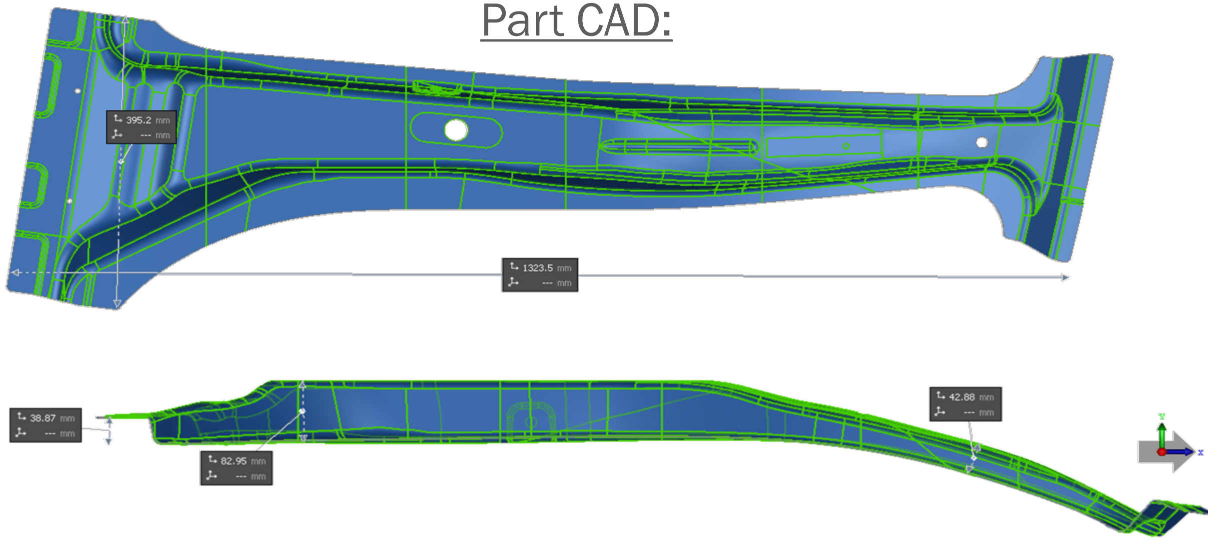






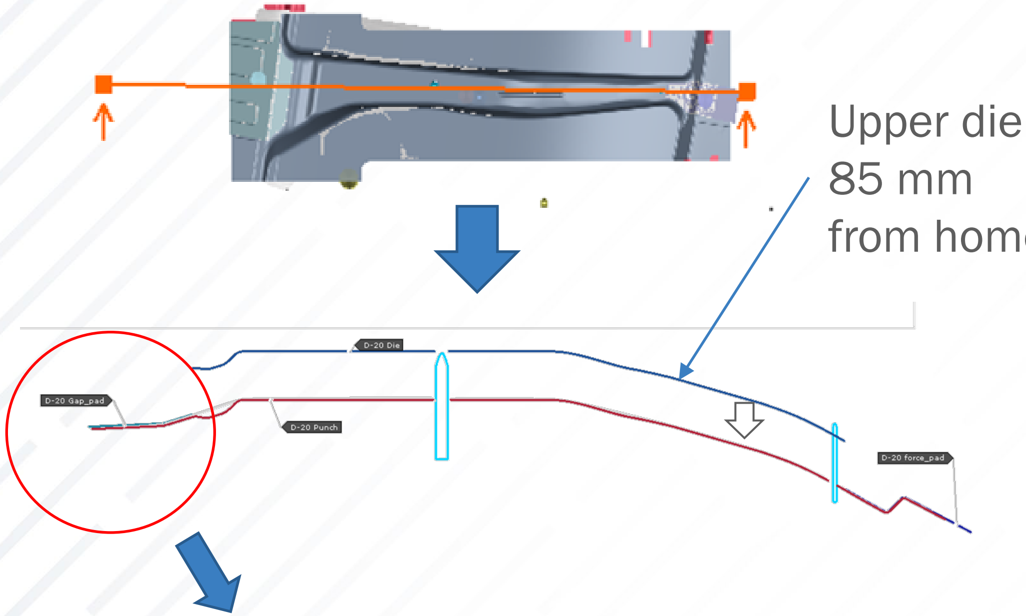
- 12,000 kN open loop hydraulic press
  - Proportional controlled hydraulic pumps to provide press force
  - Proportional controlled valves to control velocity, force, and other variables in the press process.
- Water cooling, ≈ 20 °C water temp. at exit hose.

Part CAD:



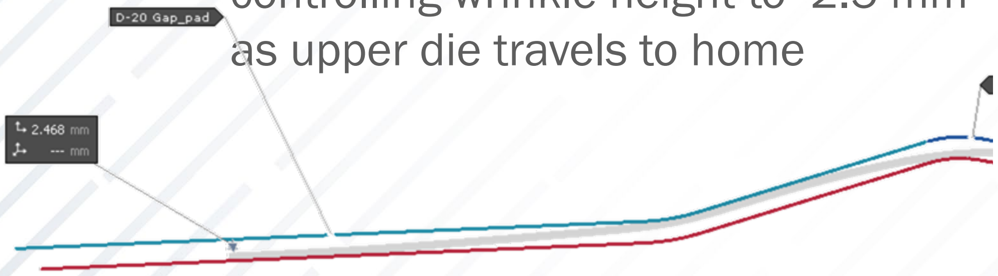
TOOLING MOTIONS / INITIAL FEA

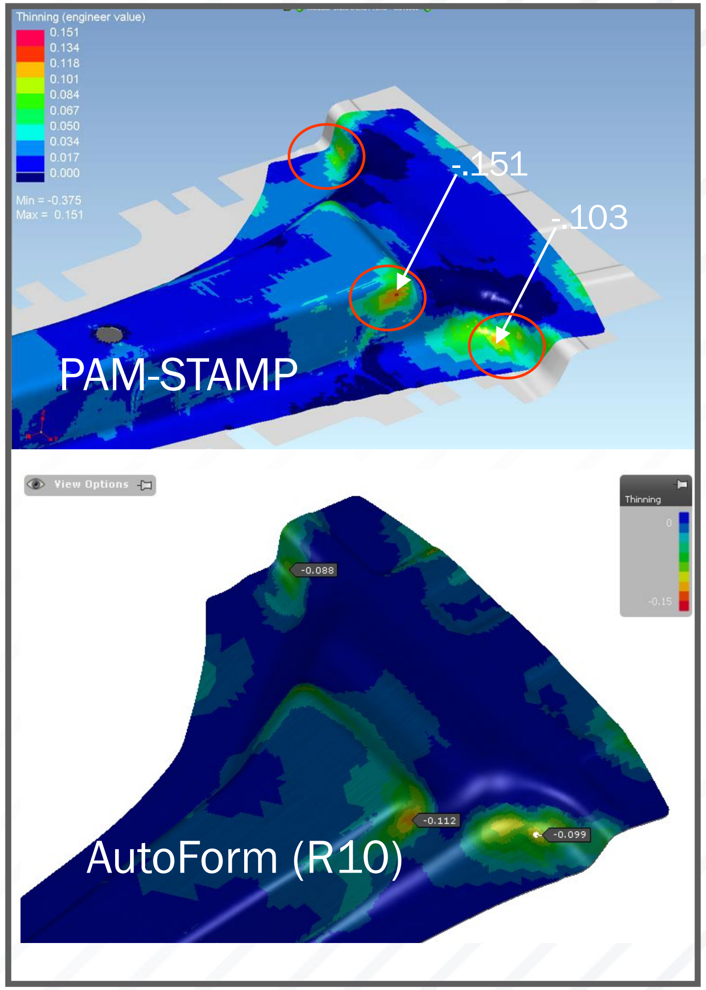
<u>Cross Section 85 mm to home</u>



Upper die
85 mm
from home

Gap pad, total gap =t +2.5 mm,
controlling wrinkle height to 2.5 mm
as upper die travels to home

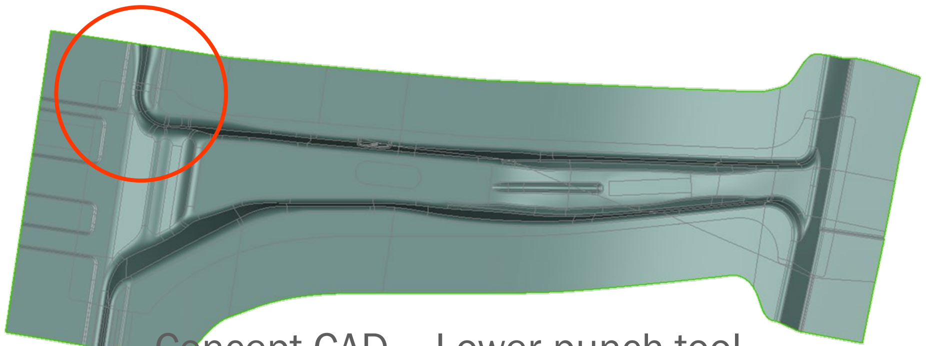


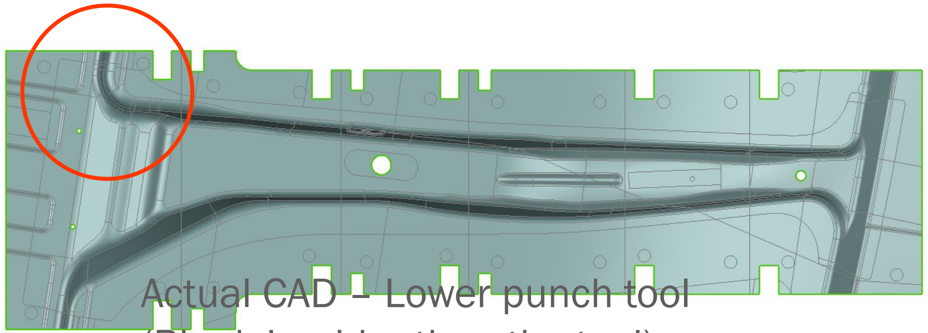


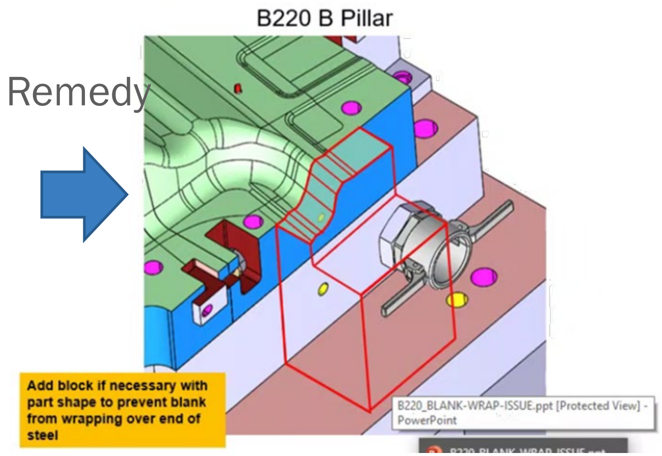
- Initial simulations:
  - Pads are set 85 mm from home
  - Slide velocity 94 mm/s 85 mm from home
  - Slide velocity 50 mm/s from 2.5 mm to home
  - Constant tool temperature

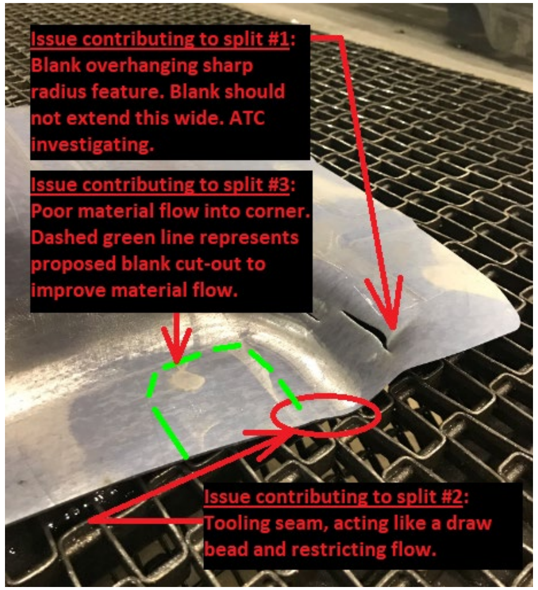
TOOLING / PROCESS DEVELOPMENT AIDED BY FEA

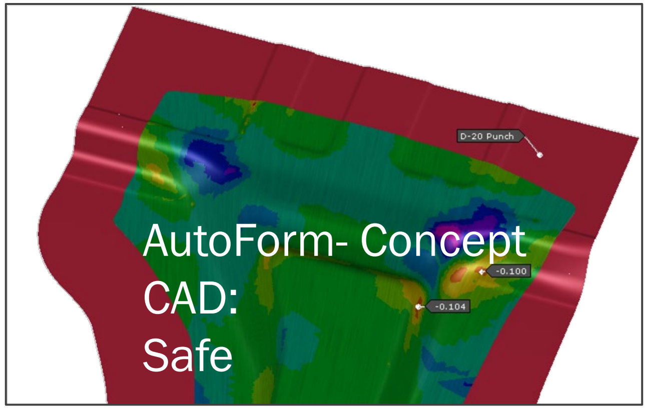
CONCEPT CAD VS. PRODUCTION CAD

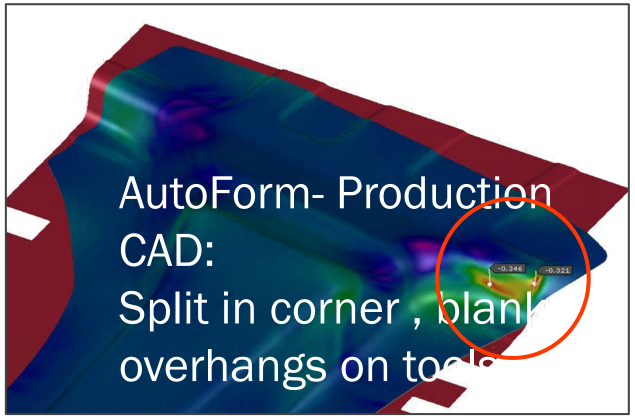


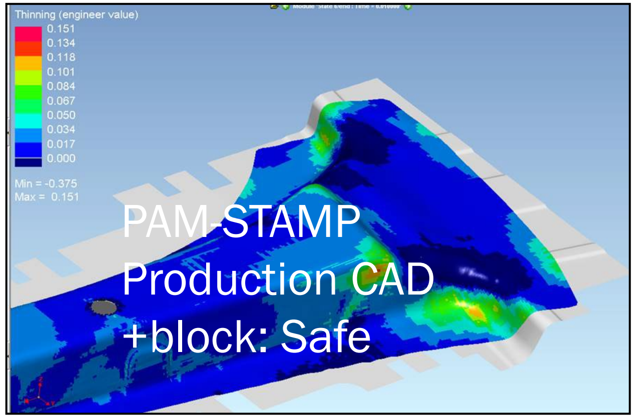






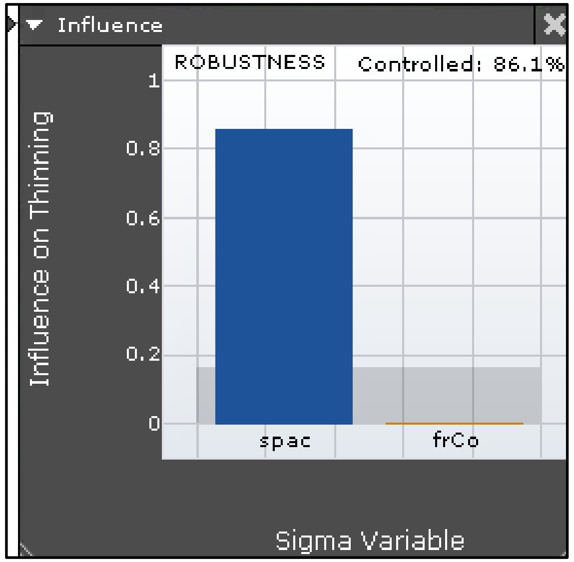


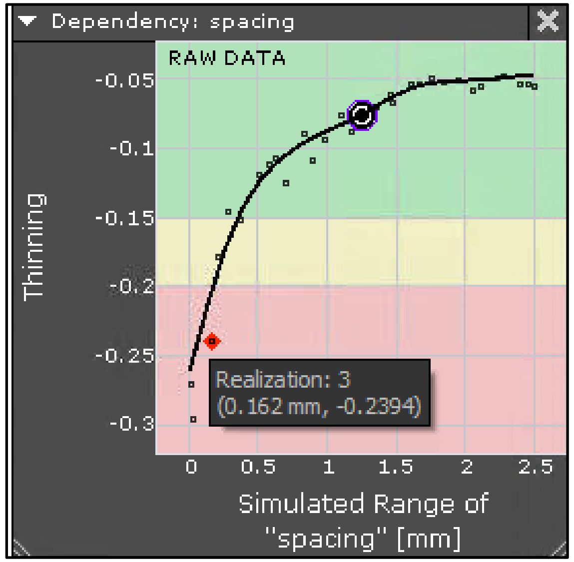


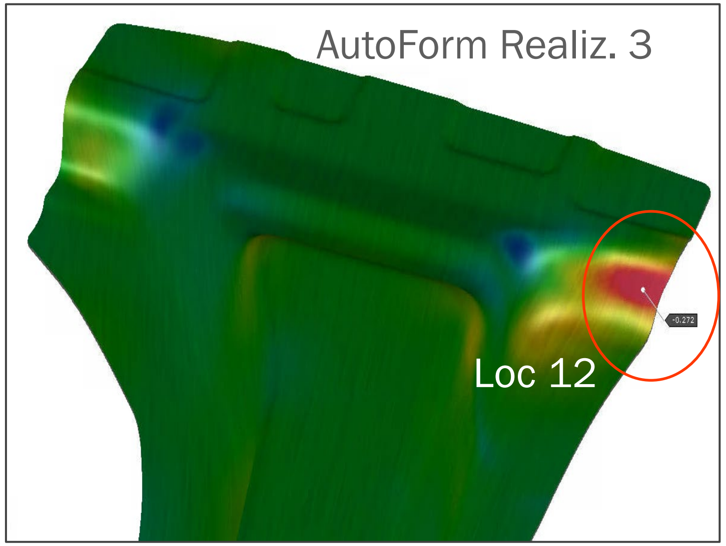


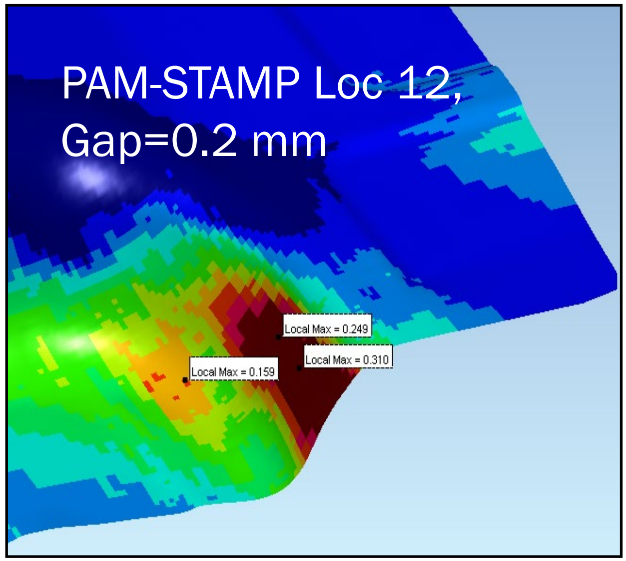
- Interpretations from FEA based on concept CAD can be a risk
- FEA should be used to check production tools

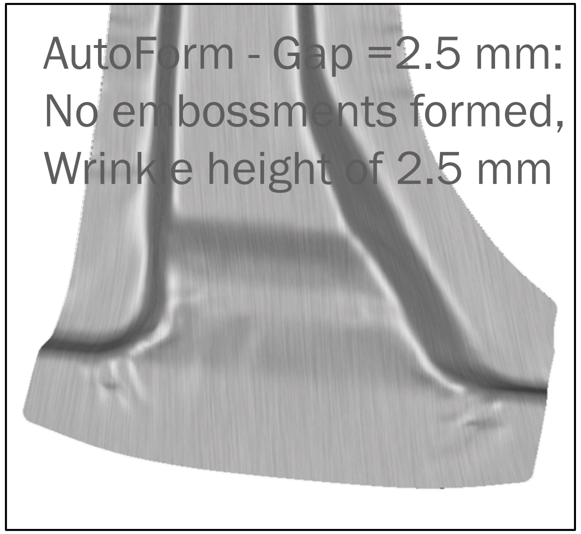
GAP PAD OPERATION FAILURE DIAGNOSED WITH FEA

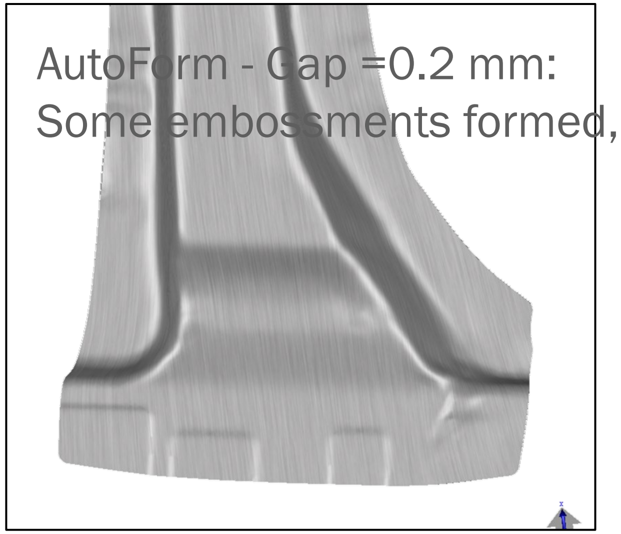


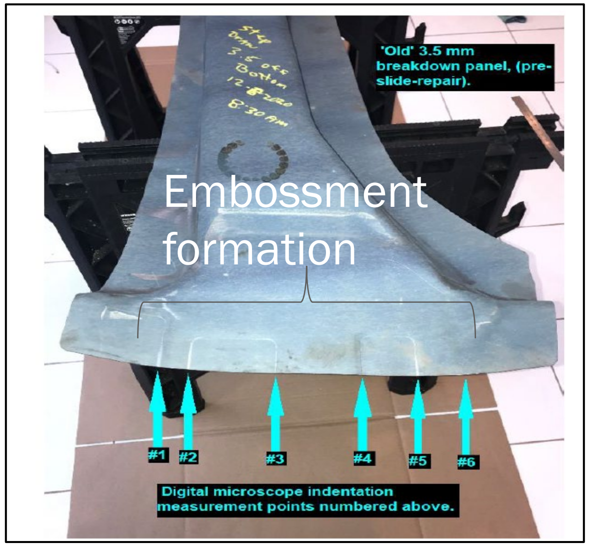


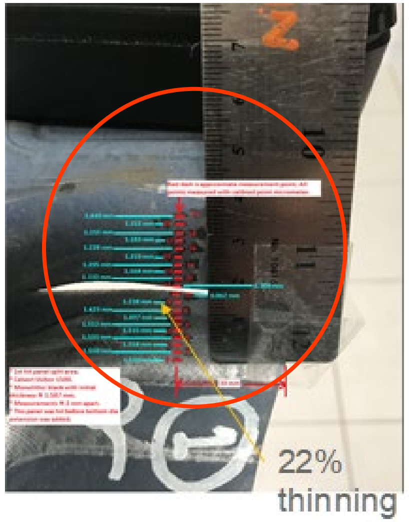




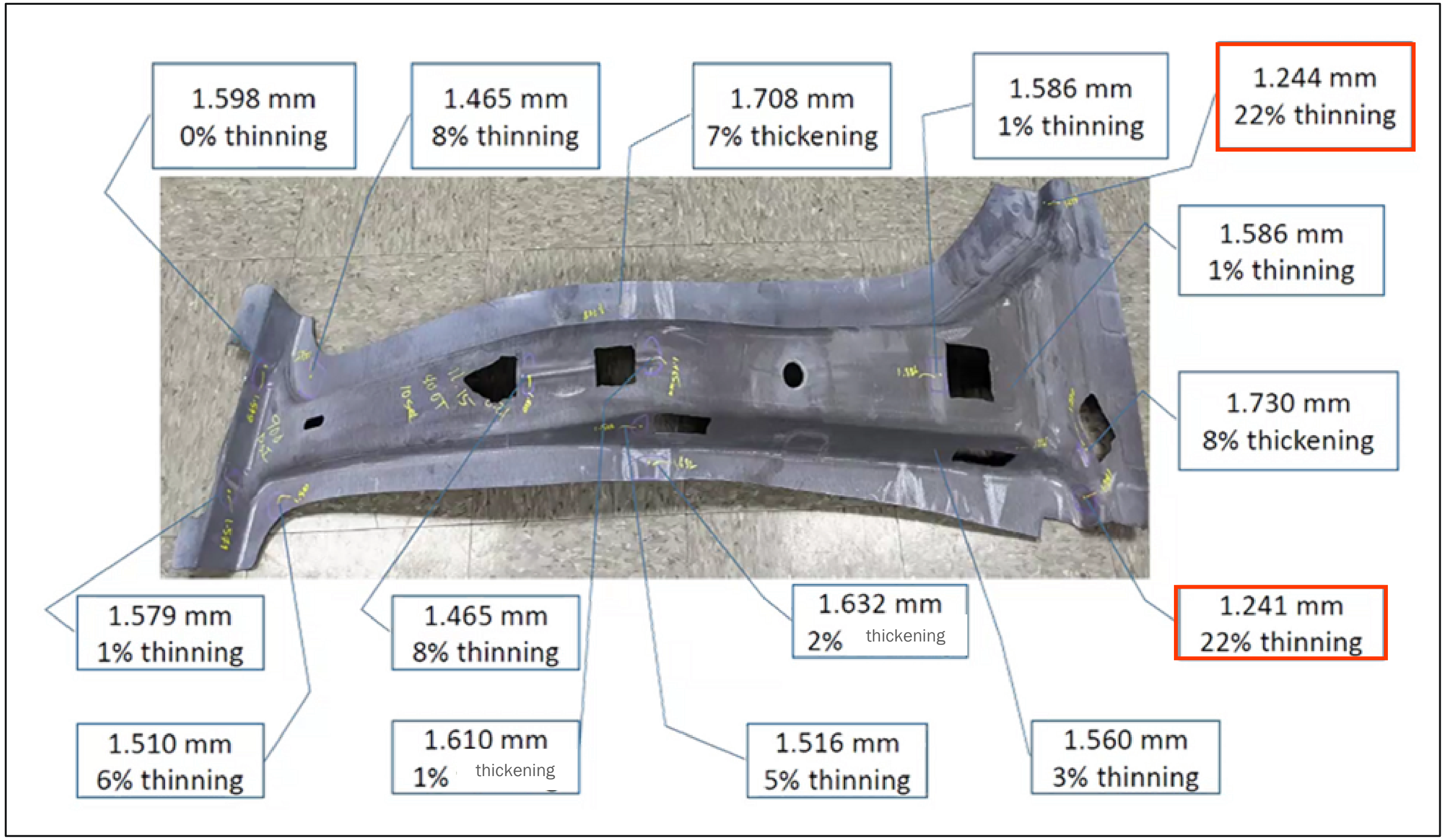


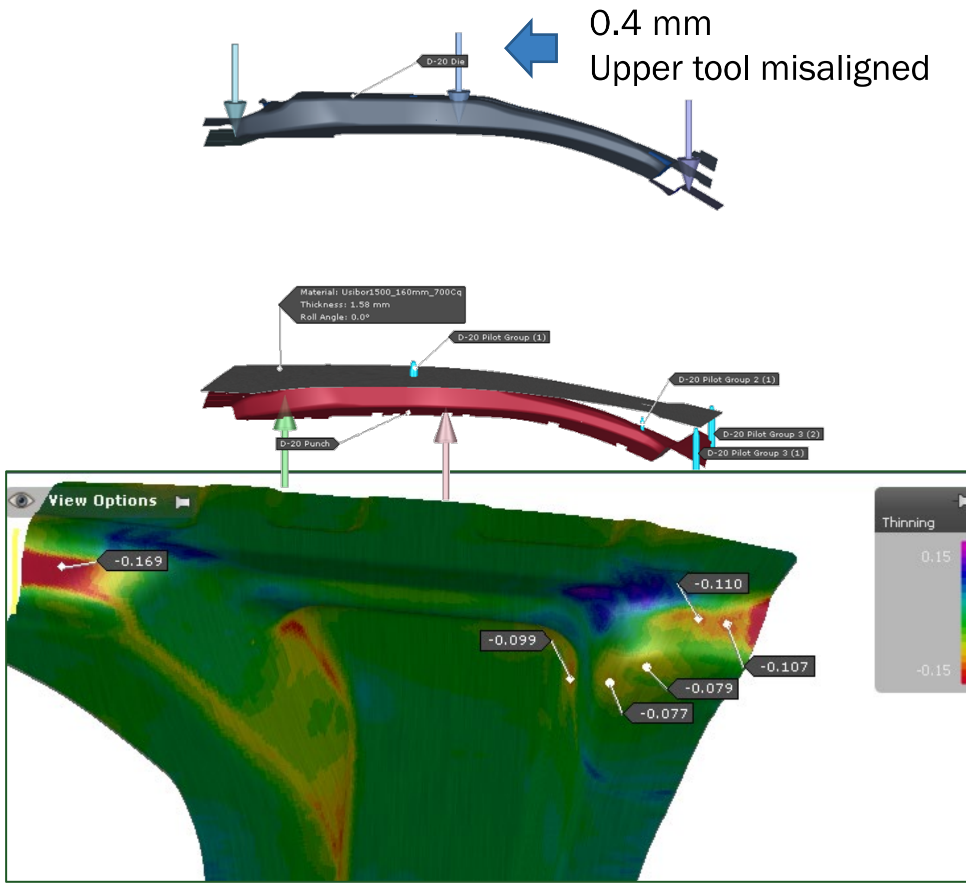






MISALIGNMENT

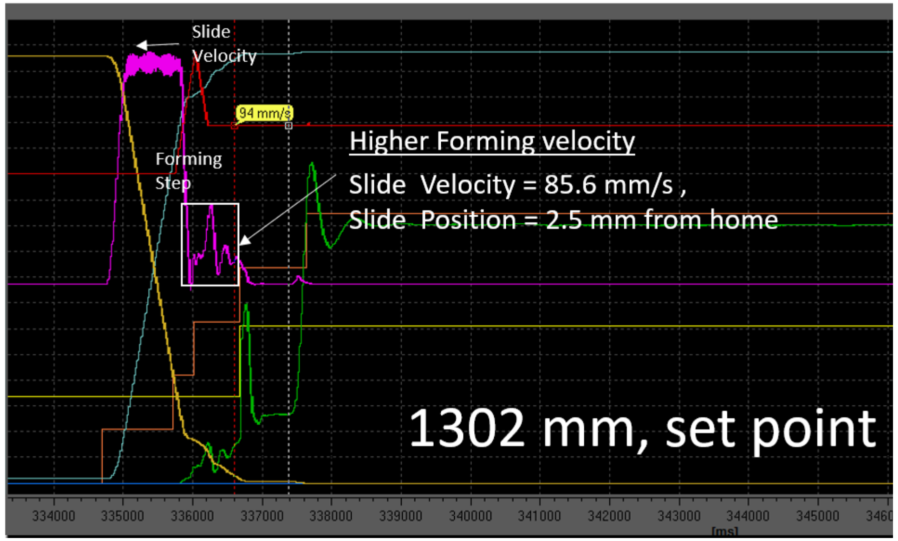




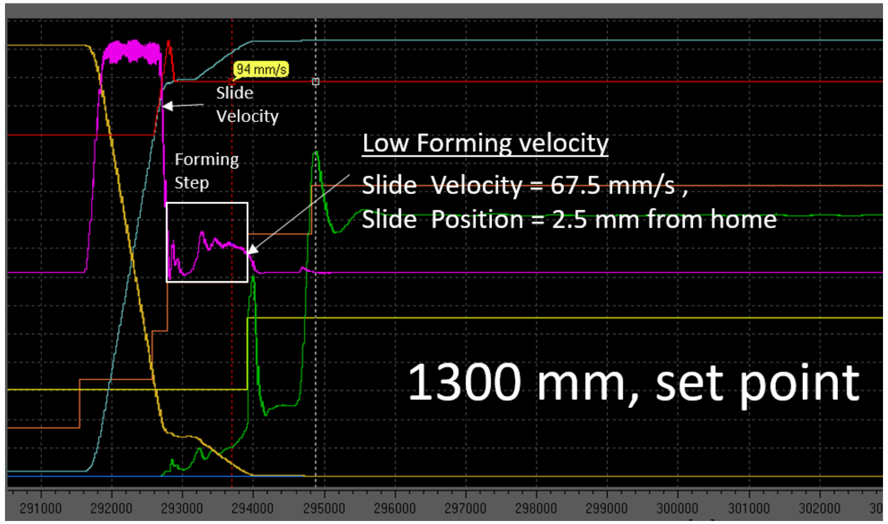
- Tooling misalignment
- Simulations could illustrate this problem

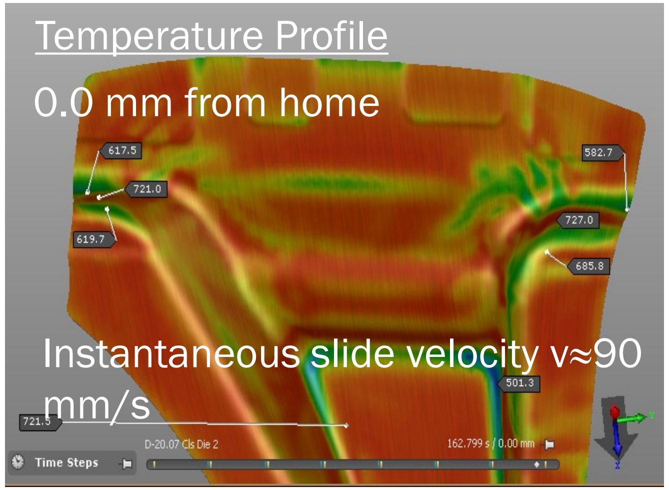
PRESS RECIPE SET UP – SLIDE VELOCITY

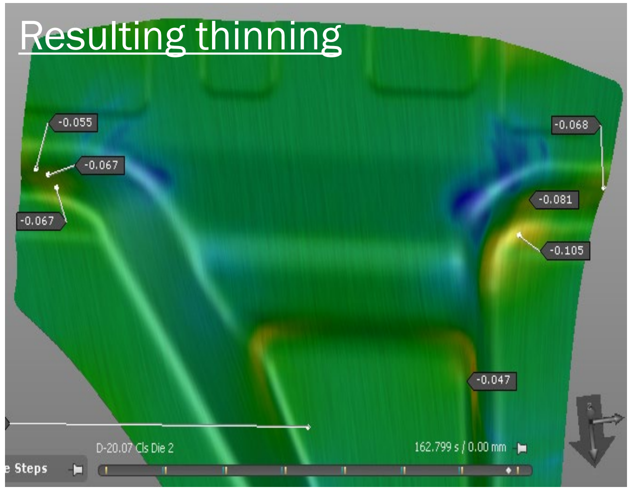
Press Trace: 1302 mm set point

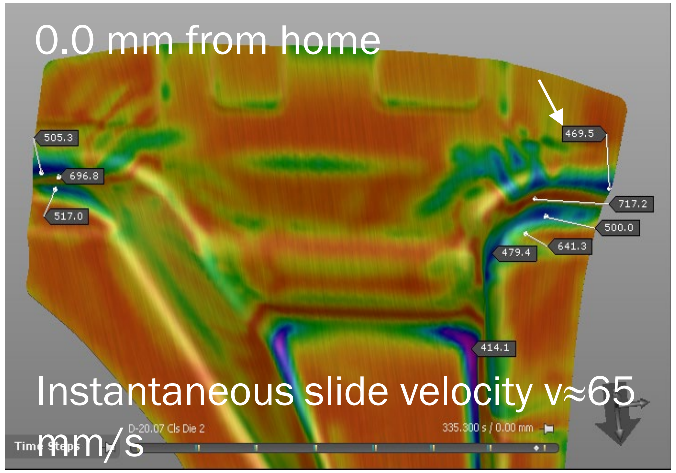


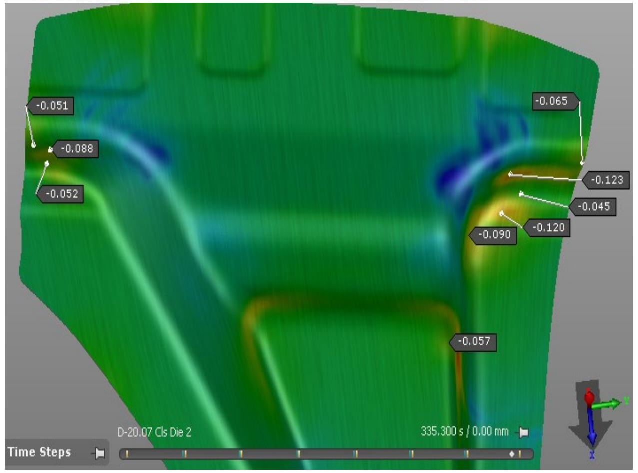
Press Trace: 1300 mm set point





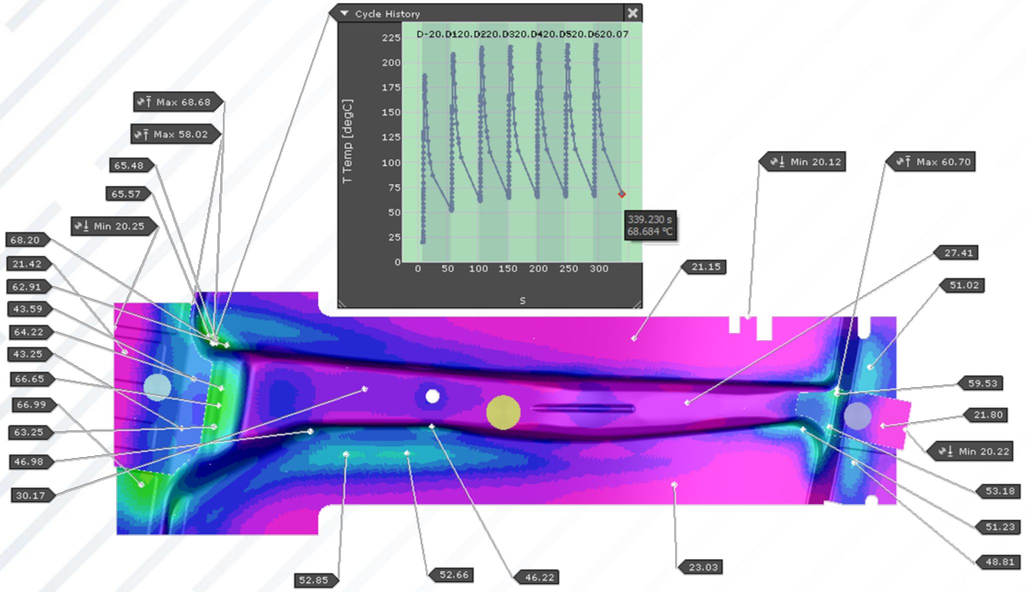




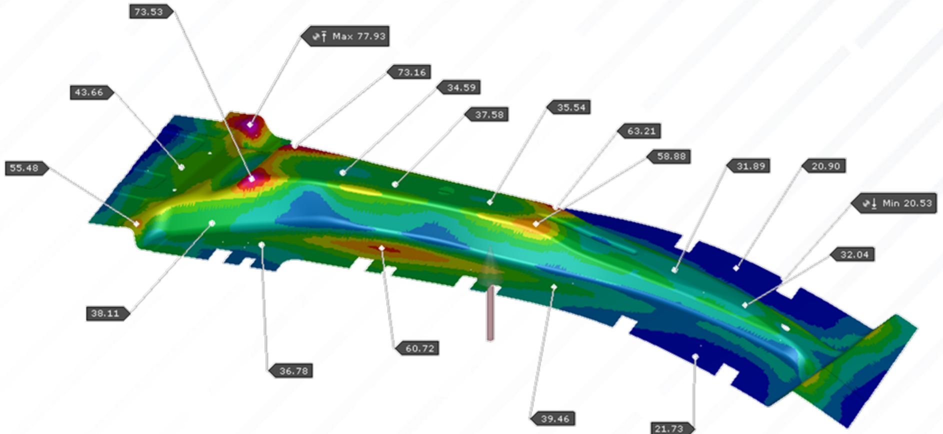


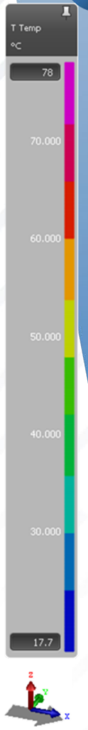
FEA TOOLING TEMPERATURE / STEADY STATE

GDIS



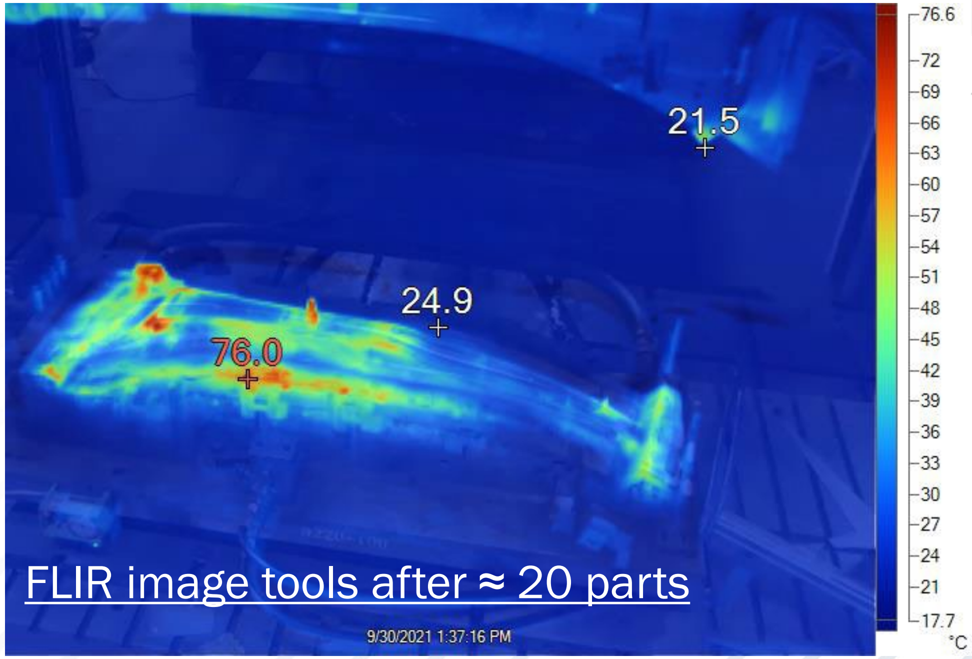
FEA Upper Die – with cooling channels





FEA lower Die – with cooling channels

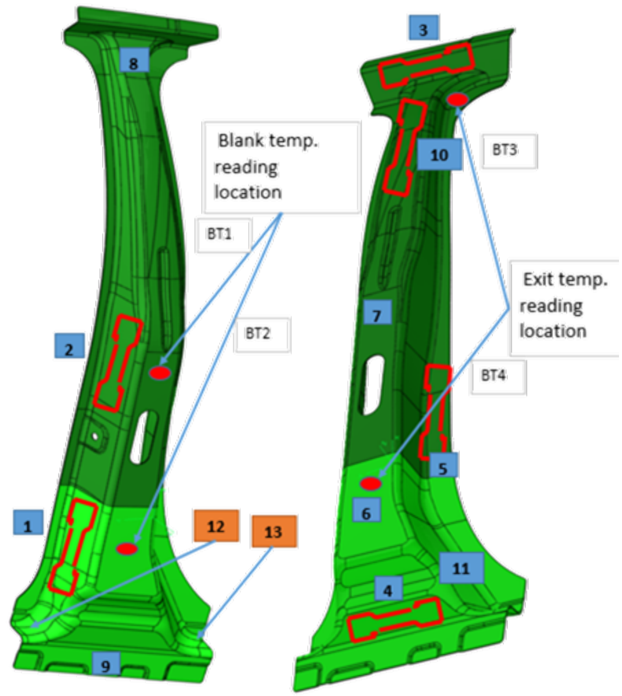
- Cooling channel evaluation
- Number of cycles until steady state
- No development of hot spots



FLIR image tools after ≈ 20 parts

BUY OFF TRIAL AND FEA

42 PIECE RUN FOR TOOLING BUY-OFF



- 7 pieces run to "warm up" tools/press
- Additional 42 pieces run

Trial Data

- Part temperatures (spot pyrometers):
- BT1, BT2 blank temperature just before forming
- BT3, BT4 part temperature just after quenching
- Thinning was measured in the walls for locations 12, 13
- Full size tensile tests performed

	Cycle Time (s)	Oven Temp (°C)	Transfer Time (s)	Part Temp start, on tools (BT1, °C)	Quench time (s)	Part Temp, tool opening (BT4, °C)	Press Tonnage (kN)
Med	48.5	933.0	12.1	753.5	9.98	122.5	3589
Min.	45	931.4	12.1	747.0	9.95	103	3558
Max.	56	936.8	12.2	756.0	10.01	132	3626

Mechanical Properties (n=5 parts throughout the run)

	YS(MPa)		TS(MPa)		TE(%)	
	Walls	Flat areas	Walls	Flat areas	Walls	Flat areas
med	1045	1030	1510	1495	6.1	6.8
min	1010	960	1460	1460	5.4	5.3
max	1110	1090	1560	1520	6.9	7.2

Thinning

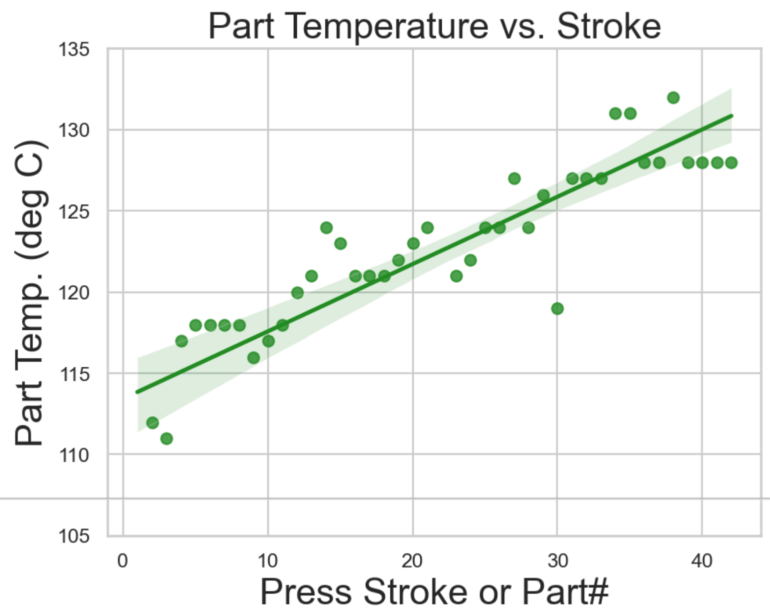
	Thinning (loc 12) Dt/t	Thinning (loc 13) Dt/t
med	-0.085	-0.106
Min	-0.109	-0.137
Max	-0.055	-0.08

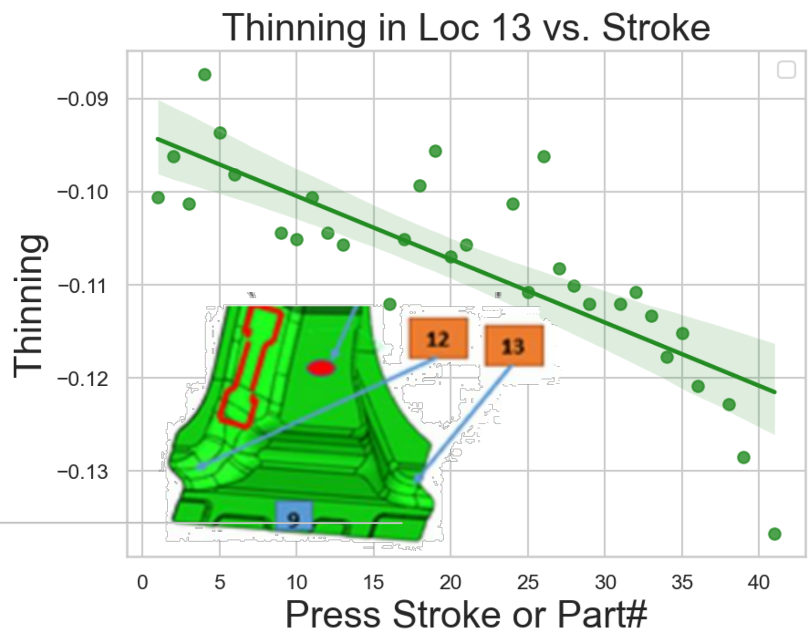
Part STL Scans compared to CAD

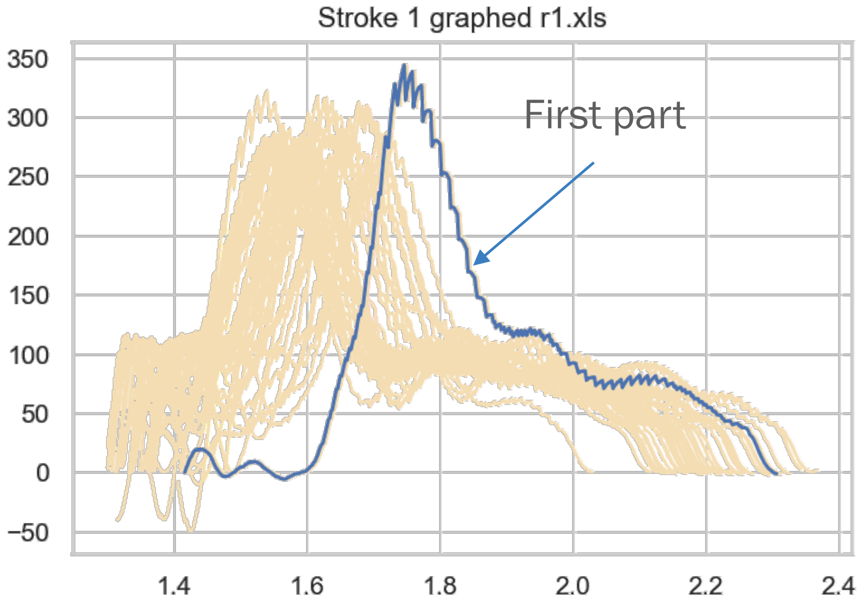
	Positive (above CAD) (mm)	Negative (below CAD) (mm)
med	2.24	-0.58
min	1.72	-0.6
max	3.34	-0.48

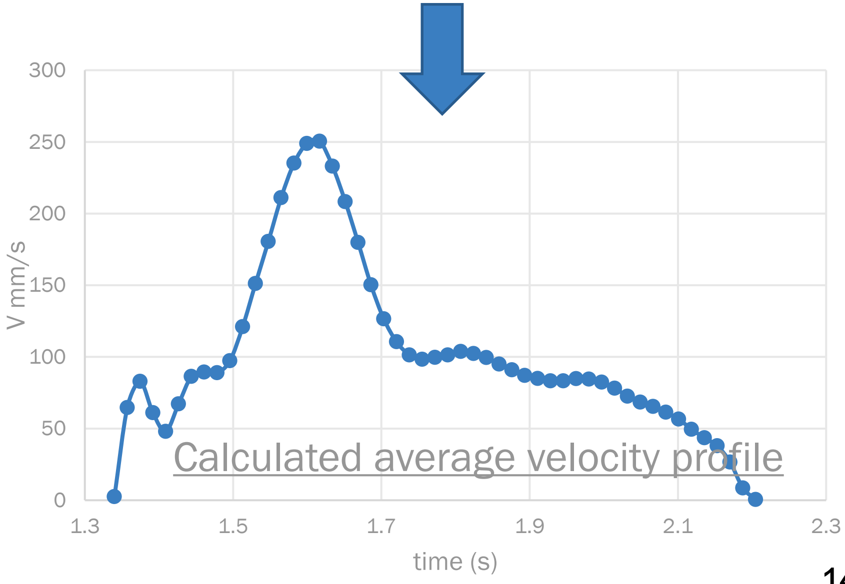
Formability is safe. Good mechanical properties, dimensional performance. ✓

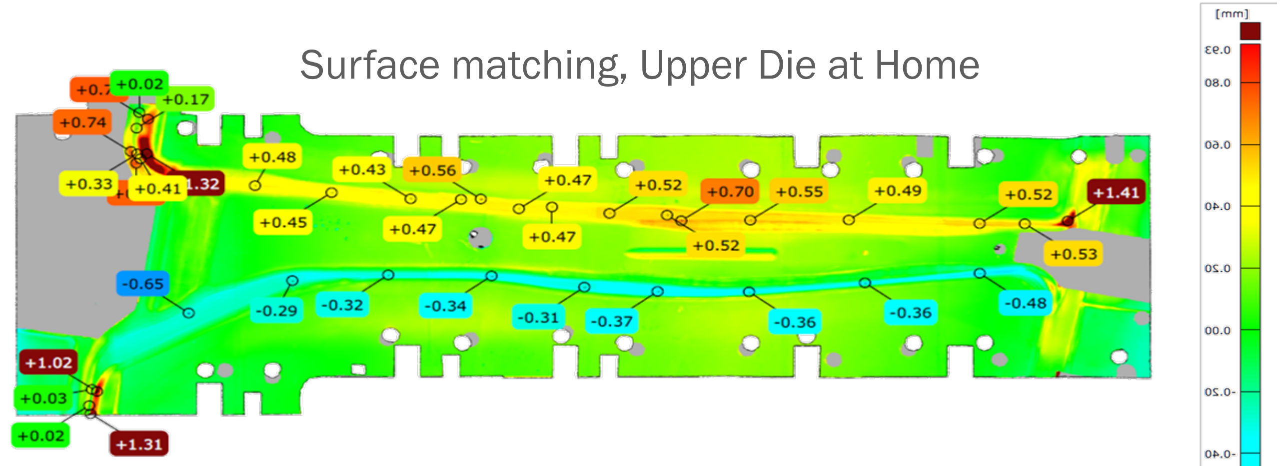
DETAILED RUNNING CONDITIONS









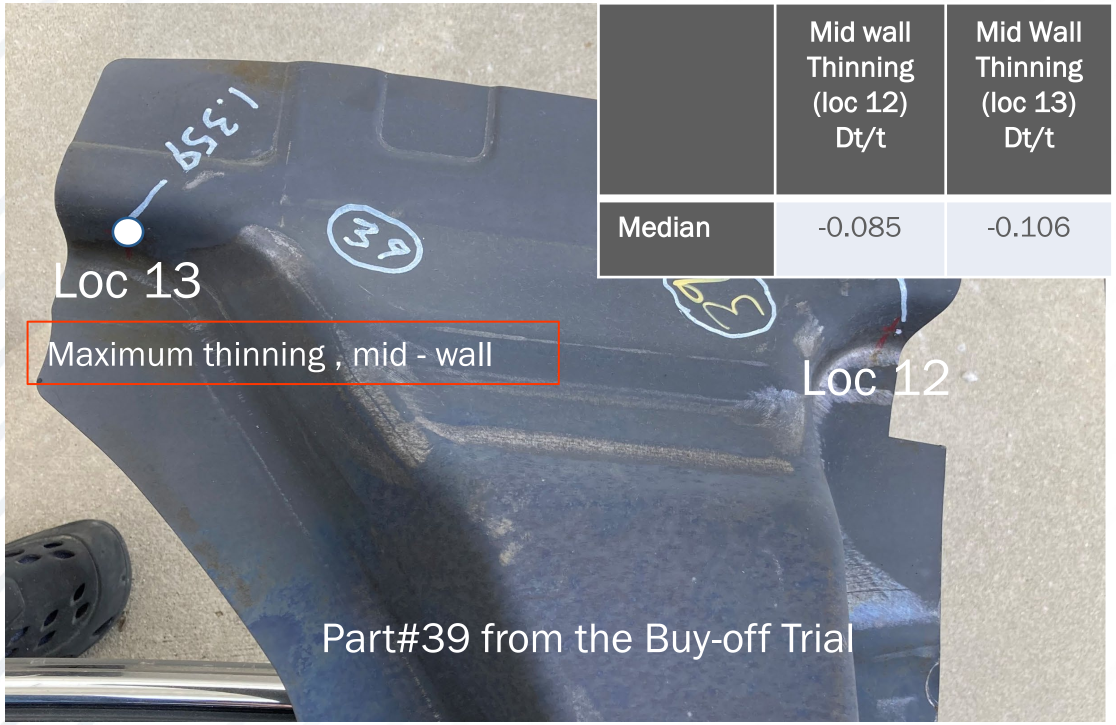


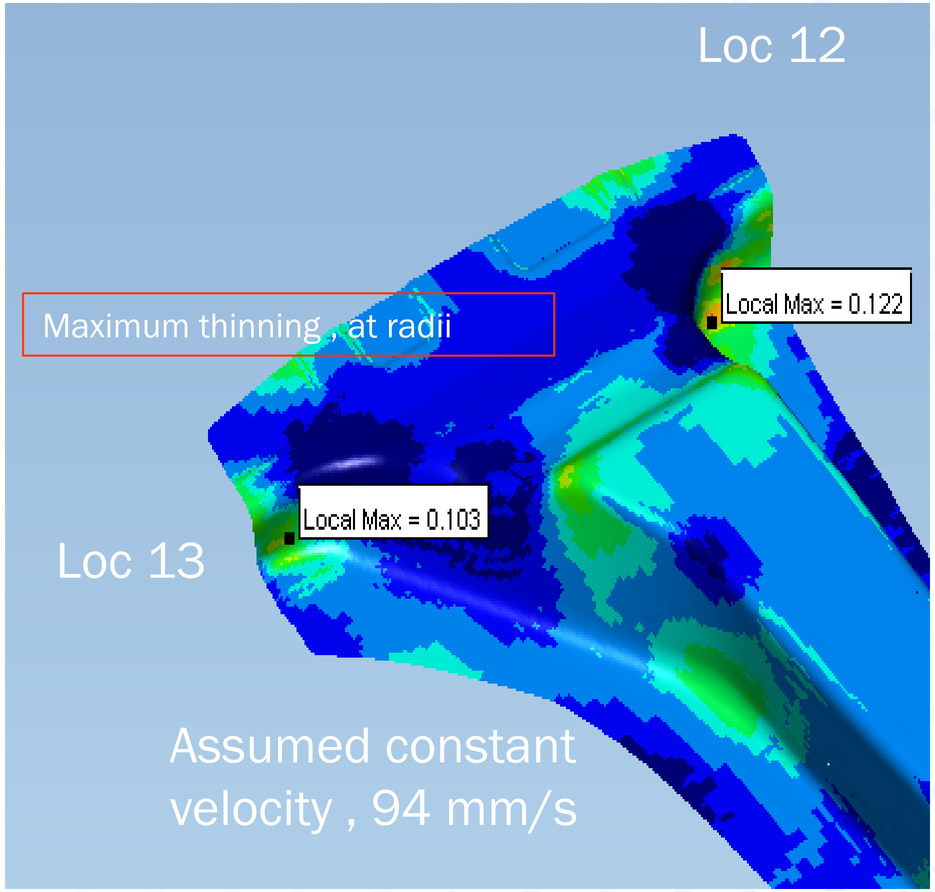
Y
Z X

Upper die tooling compared to lower die tooling offset by 1.58 mm

PAM-STAMP FEA USING CONSTANT VELOCITY ASSUMPTION AND TOOLING CAD

	Mid wall Thinning (loc 12) Dt/t	Mid Wall Thinning (loc 13) Dt/t
Median	-0.085	-0.106

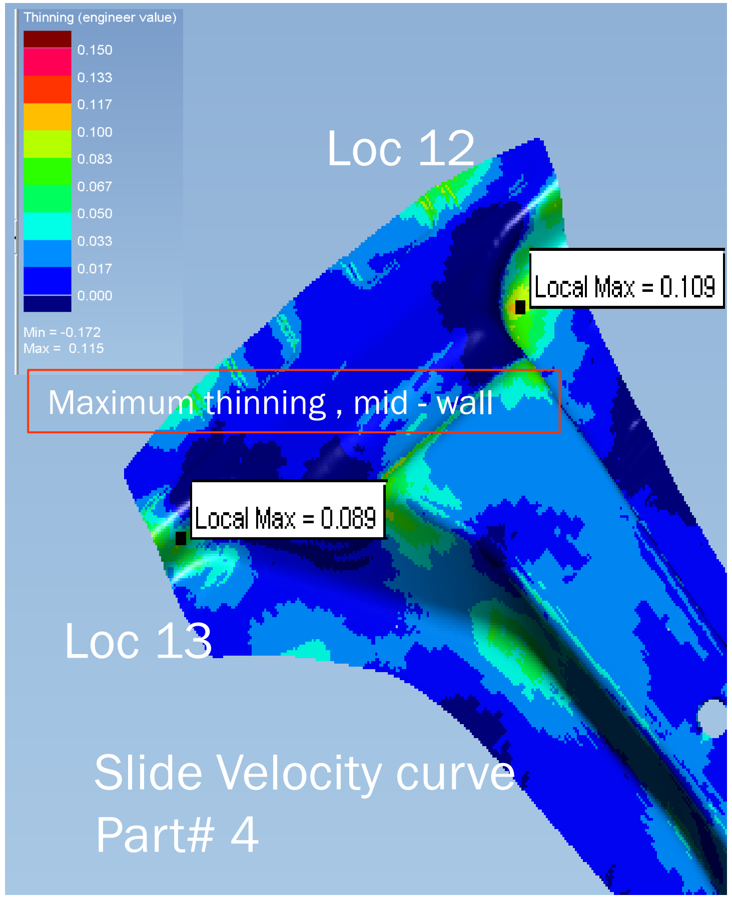


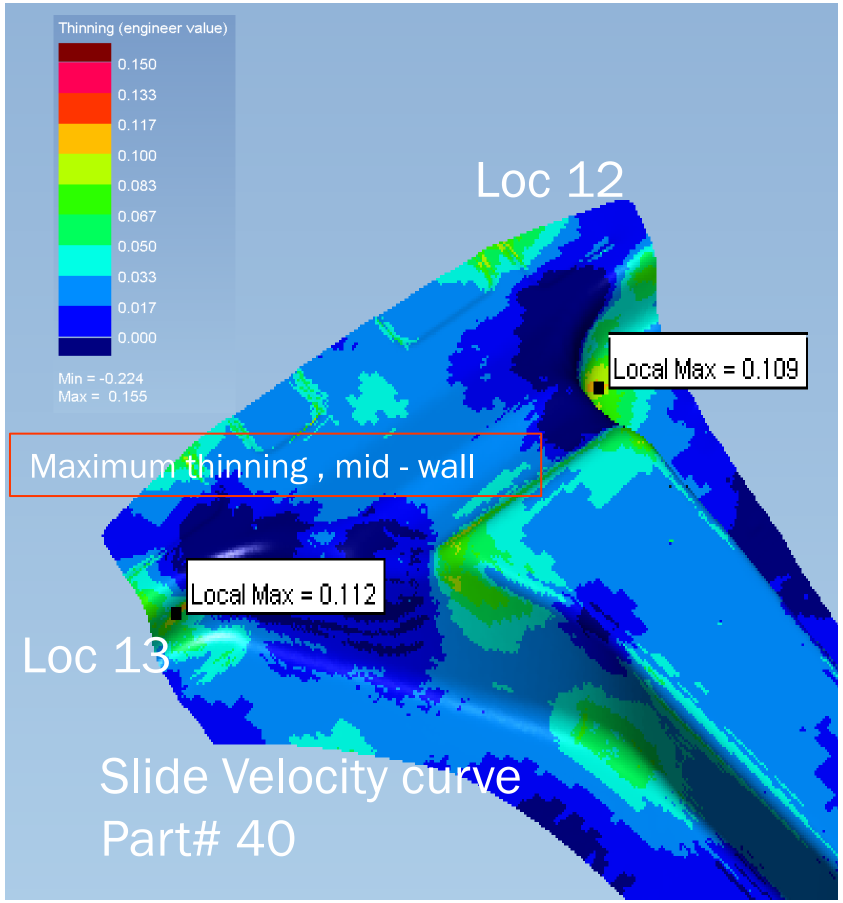


- FEA predicts different location of maximum thinning vs. the buy-off trial

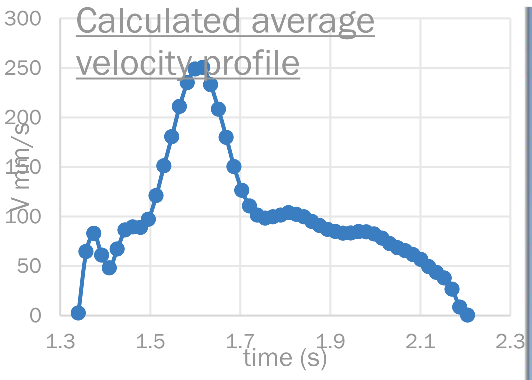
PAM-STAMP FEA USING STL, ACTUAL PRESS SLIDE VELOCITY CURVES - BETTER THINNING PREDICTIONS

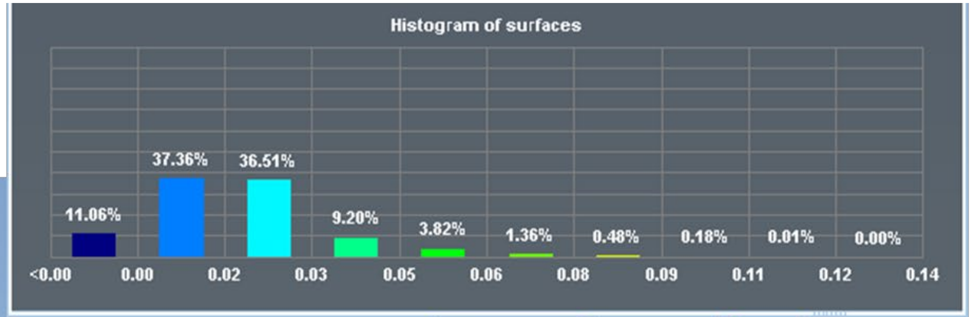
- FEA using actual velocity curves (Part#4, Part#40):
  - Matches the location of maximum thinning from the trial (mid wall)
  - The thinning trend from the trial is reproduced in the FEA
  - In the trail at Loc 13, thinning increases from -0.087 (Part#4) to -0.137 (Part#40)

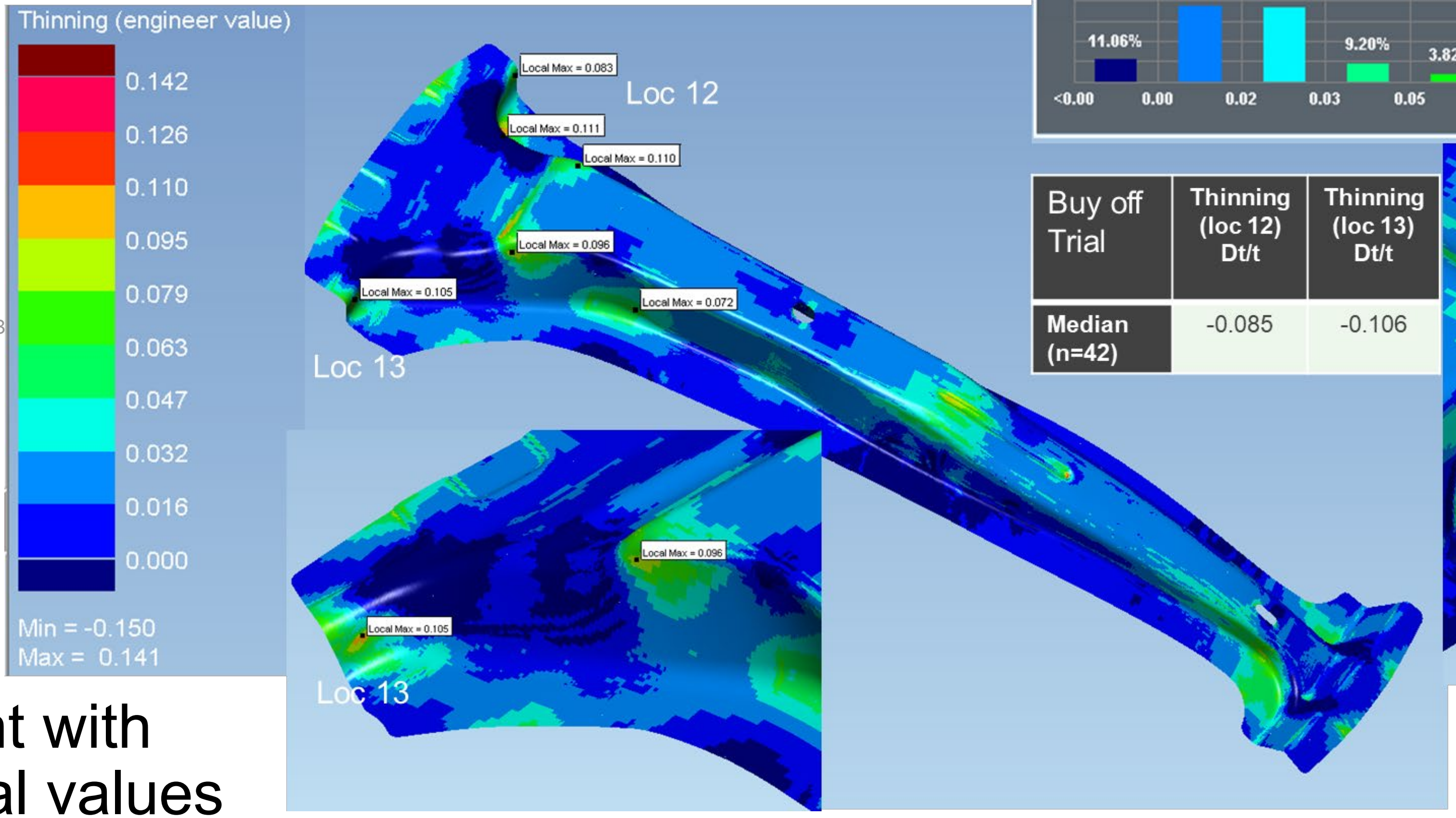




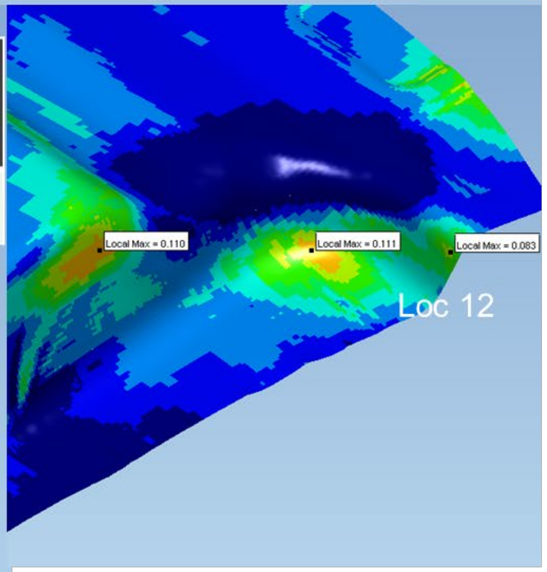
PAM-STAMP THINNING USING STL, CALCULATED AVERAGE OF PRESS SLIDE VELOCITY CURVES





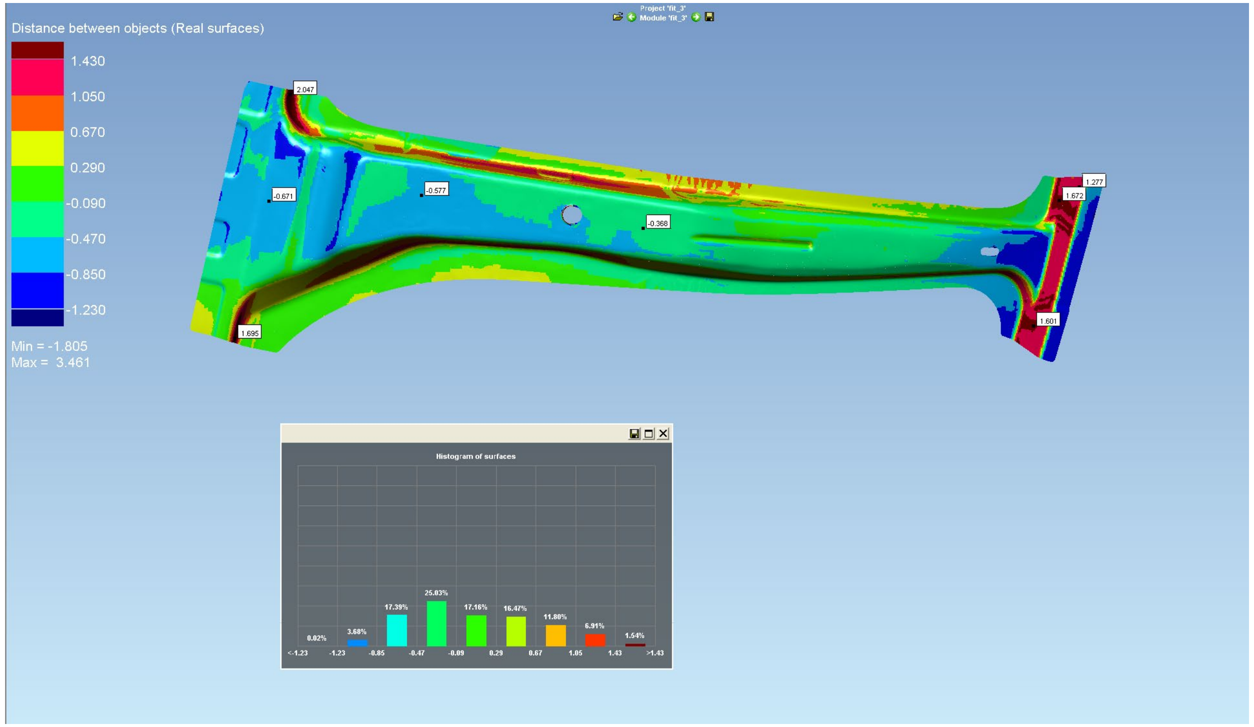


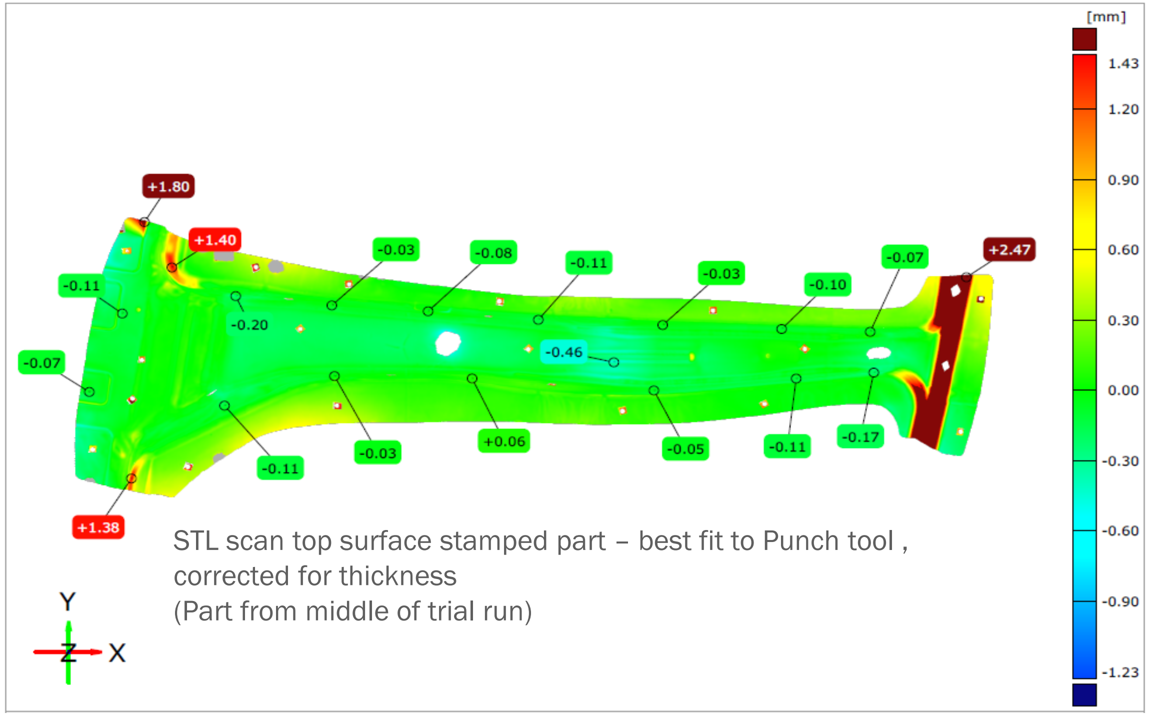
Buy off Trial	Thinning (loc 12) Dt/t	Thinning (loc 13) Dt/t
Median (n=42)	-0.085	-0.106



Good agreement with location, and trial values

PAM-STAMP DISTORTION USING STL, CALCULATED AVERAGE OF PRESS SLIDE VELOCITY CURVES

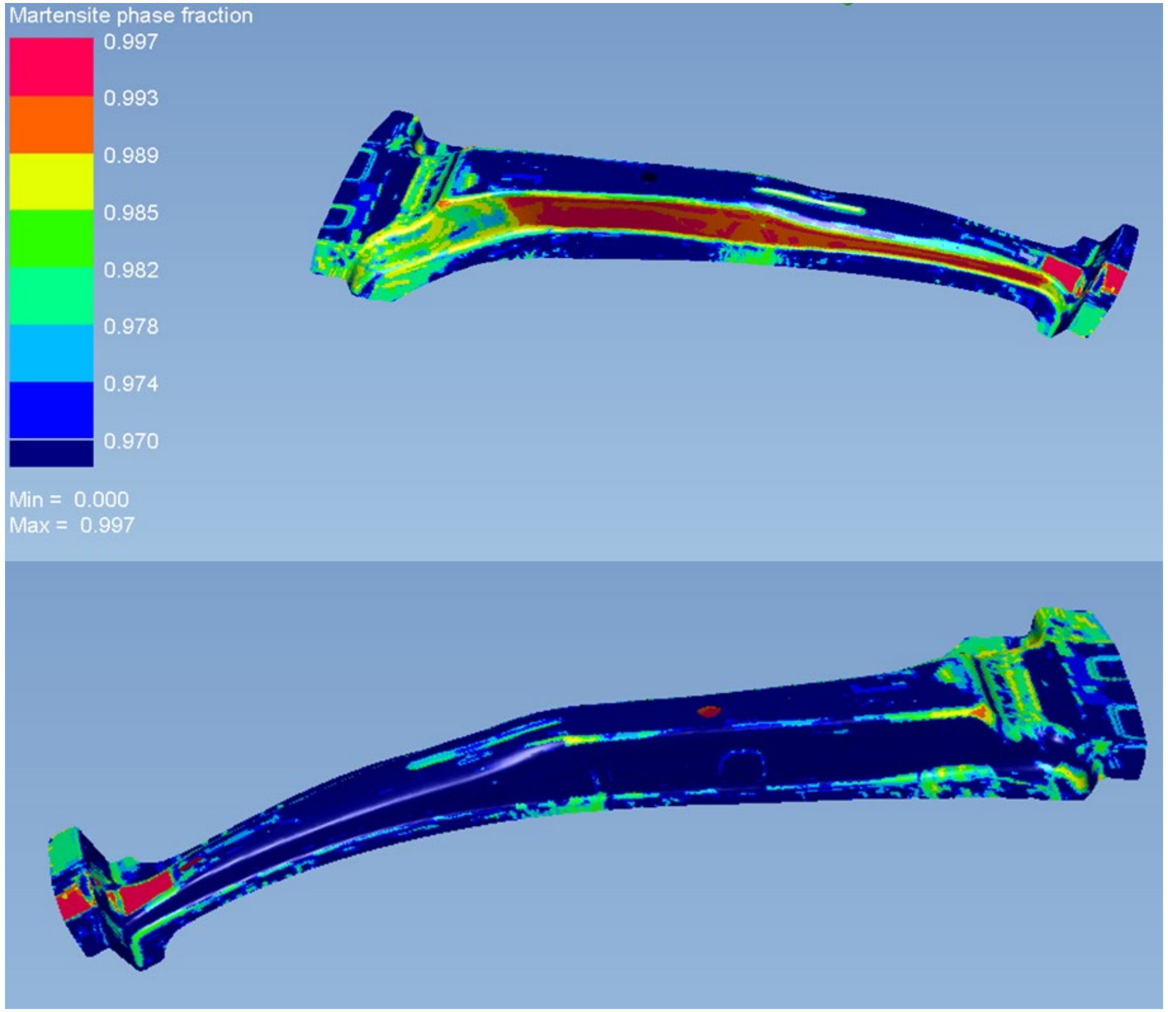


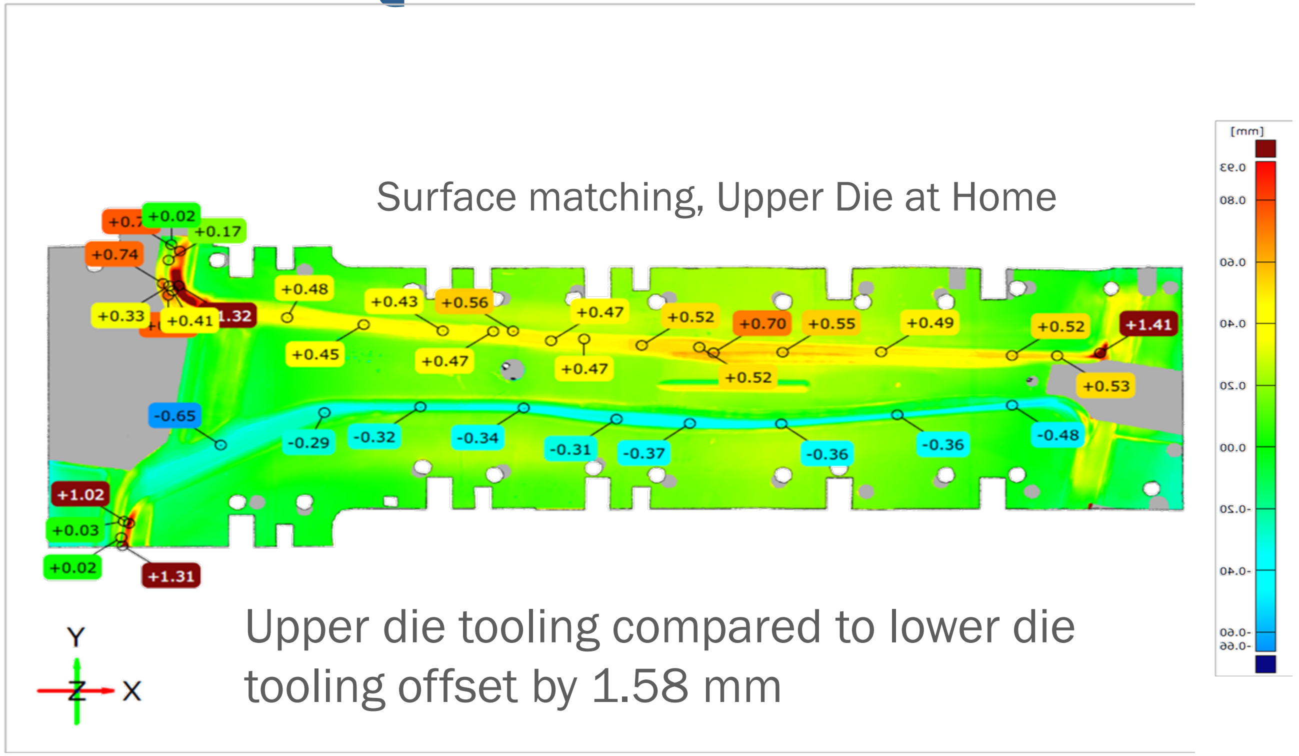


STL scan top surface stamped part – best fit to Punch tool , corrected for thickness
(Part from middle of trial run)

- Min/Max predicted distortion magnitudes are less than that seen in the trial
- Also, the pattern of distortion is similar to that in the trial

PAM-STAMP FEA USING STL, MEASURED PRESS SLIDE VELOCITY CURVES: QUENCHED AFTER 10 S, 3600 KN





- The effect of tooling gap in the walls in the scanned (STL) tools is reflected in the simulation quenched results
- The part is > 97% martensite, in alignment with the good mechanical properties from the trial

SUMMARY, FUTURE WORK AND NEXT STEPS

SUMMARY

- Benefits of FEA simulation of tooling commissioning demonstrated in:
  - Assessing production intent tooling CAD vs. concept CAD
  - Diagnosing gap pad failure
  - Assessing the effect of misalignment
  - Aid to making decisions for the press “recipe”
  - 3D thermal simulations show promise to determine hot spots on tools
- Tooling Buy Off:
  - Good parts made using 1.6 mm PHS 1500 AS
  - Able to measure press stroke variations (slide velocity, quench force, timing)
  - Good agreement between simulation and trials,
  - FEA predictions for thinning were more in agreement with the trial results when actual velocity curves from the trial were used in the simulation instead of assumed constant velocity.
  - Predicted martensite fraction in-line with good mechanical properties measured in parts from the trial
  - Predicting part distortion (with FEA) is a challenge, magnitudes were underpredicted , but trend is somewhat correctly predicted

NEXT STEPS

- Model stamping process noise effects on stamped product consistency
  - Development of FEA robustness (Monte Carlo) simulations of the hot stamping process incorporating process variation
  - Net shape hot stamping modeling, stability of the part edge with respect to holding part tolerances.
- Ongoing process window for new grades, new coatings etc.
- FEA modeling ongoing improvement:
  - Development and validation of material cards, and prediction of mechanical properties
  - Improve understanding of heat transfer and part distortion

FOR MORE INFORMATION

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