GREAT DESIGNS IN STEEL

THE EFFECT OF COMBINATION BEADS ON SPRINGBACK: EXPERIMENTAL STUDY & VIRTUAL STUDY

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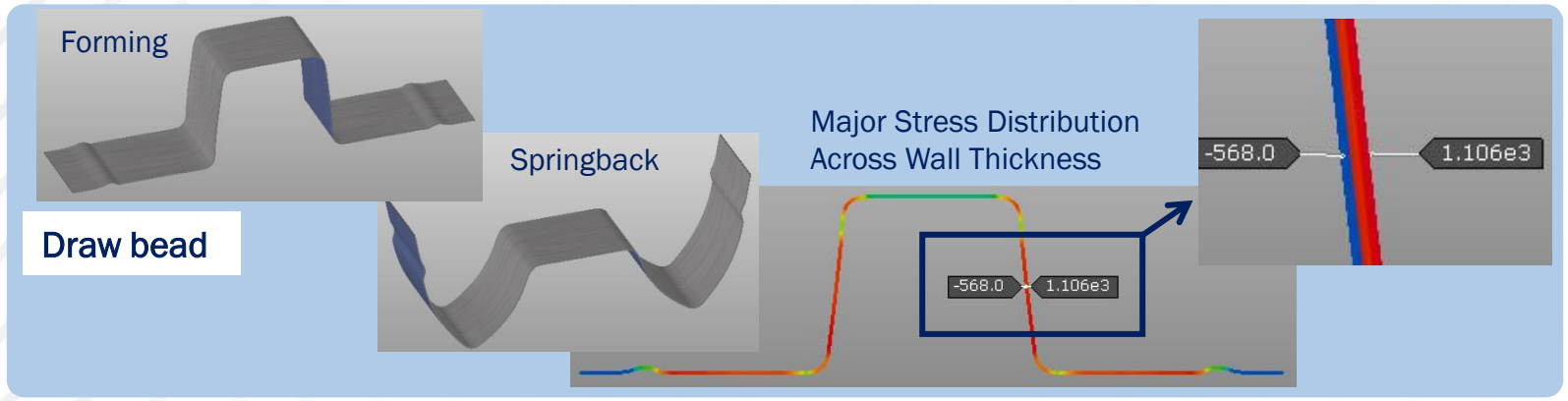
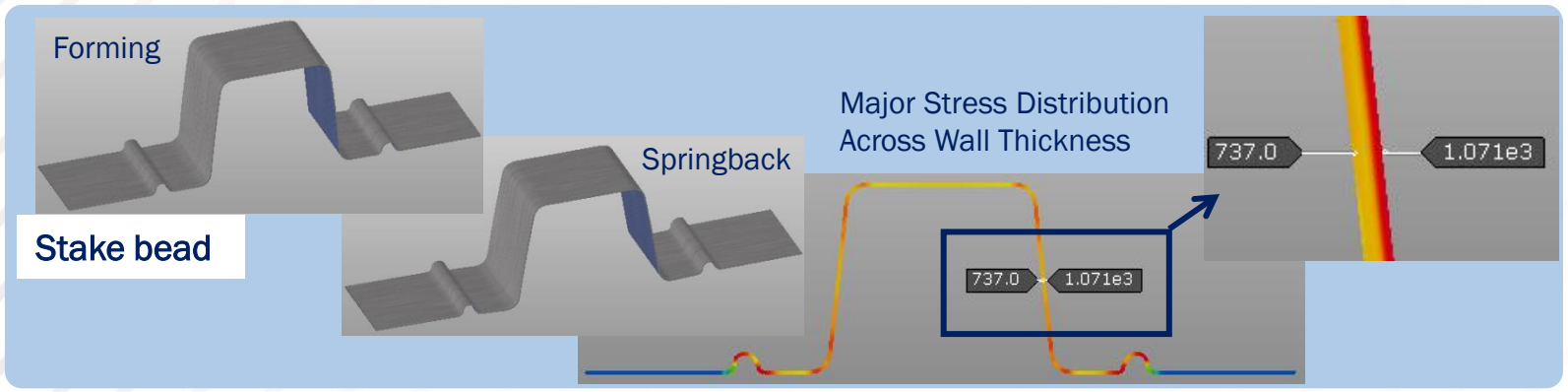
OBJECTIVE

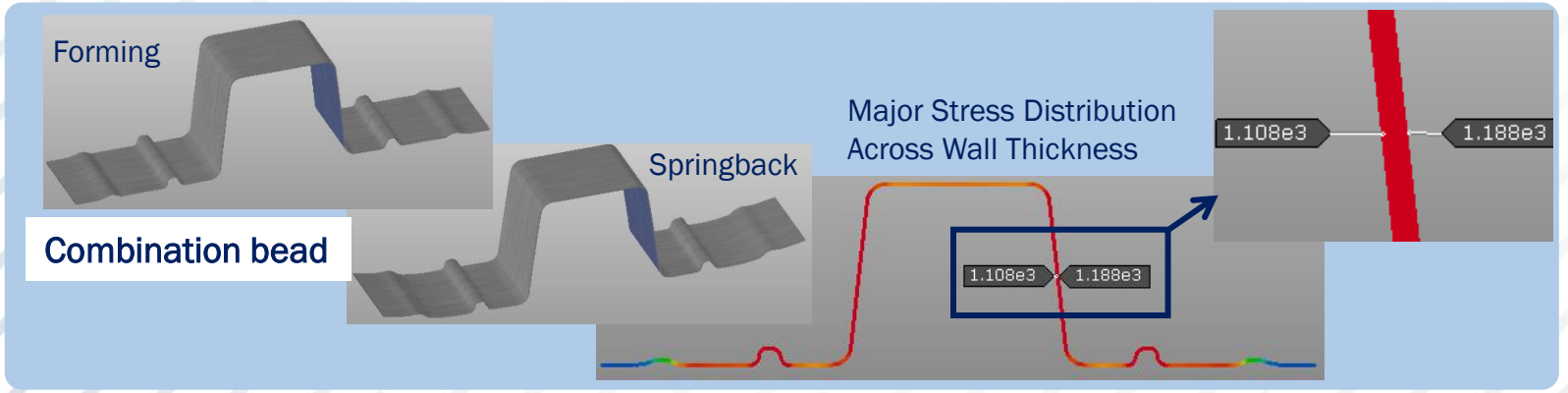
To Investigate the Effects of the Combination of Draw Bead and Stake Bead in Springback Management on 3rd Gen AHSS

An Auto/Steel Partnership Stamping Team Project

STRESS EQUALIZATION VS. SPRINGBACK





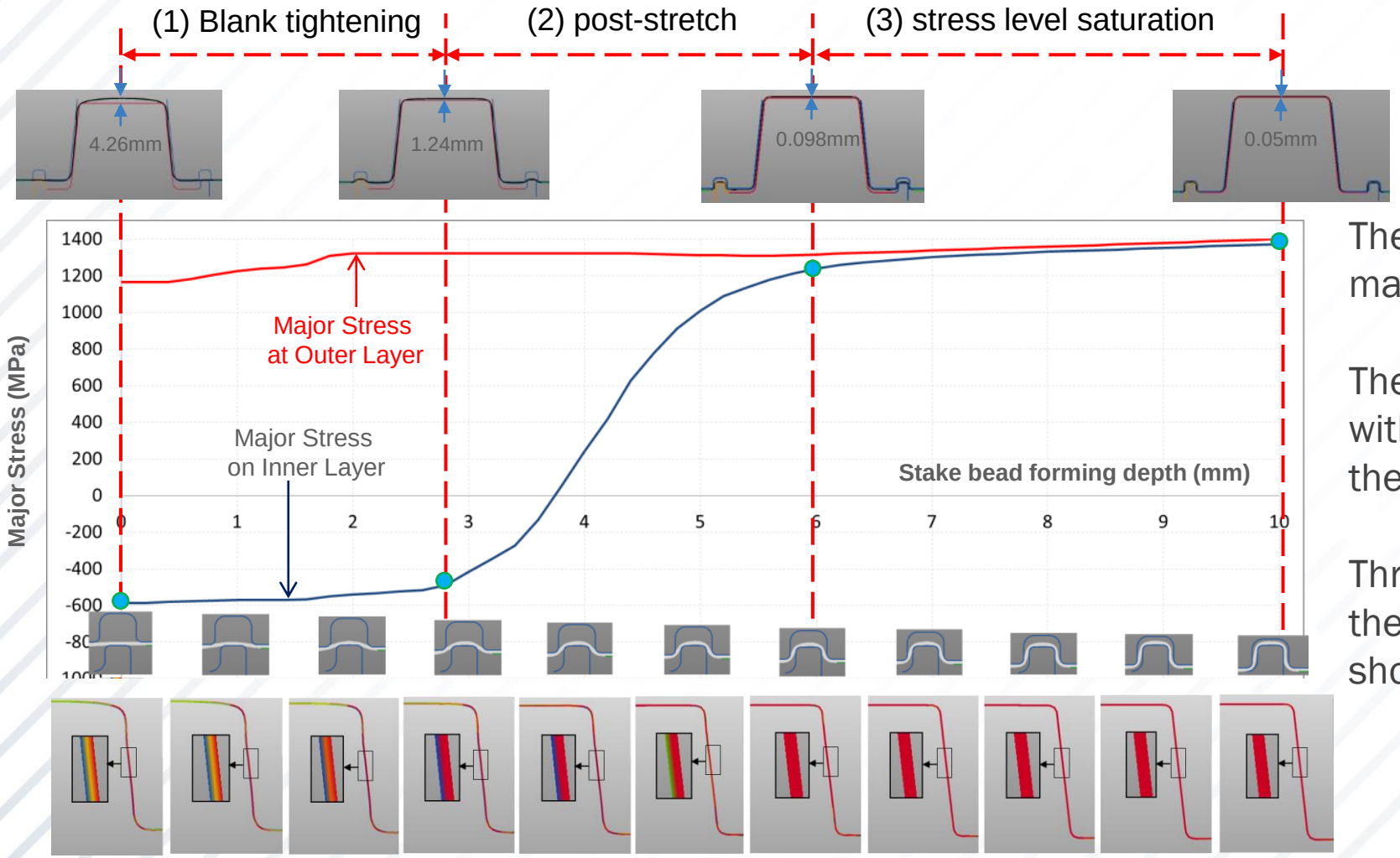


Stress distribution across wall thickness is closely related to springback

Equalized stress distribution achieves better springback control

Optimized bead combinations promotes to approach stress equalization

BEAD STRETCHING VS. STRESS EQUALIZATION



The contour shows the level of absolute major stress.

The progressive bead forming is shown with 1mm interval, synchronized with the evolution of stress difference.

Three stages are divided by dash lines, the bead forming progressions are shown at bottom

COMBINATION BEAD FORMING PROCESS

Drawn blank is drawn over and passed draw bead

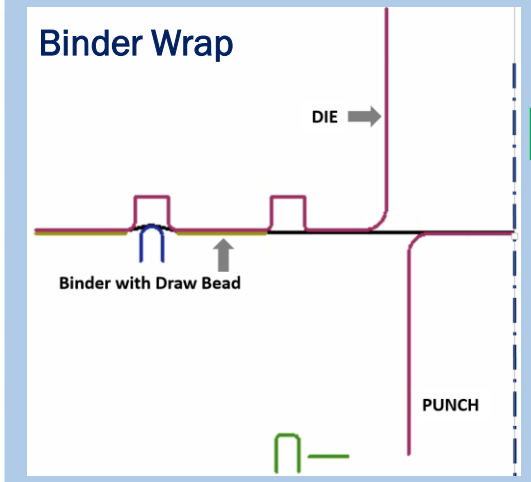
Upper Die

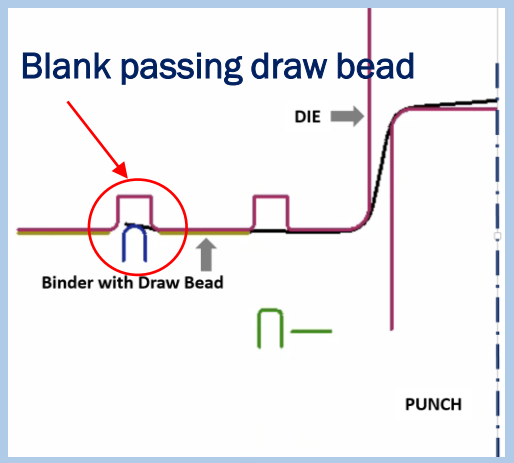
Binder with Draw Bead

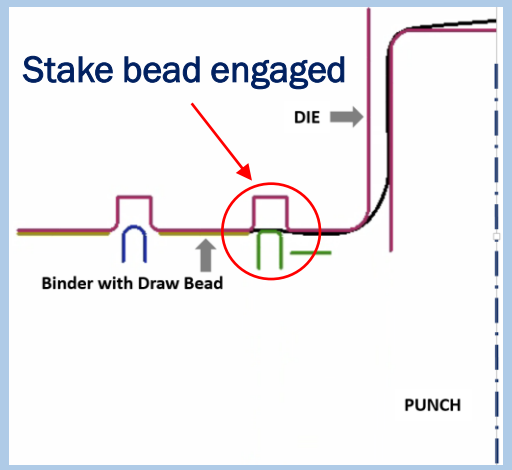
Punch

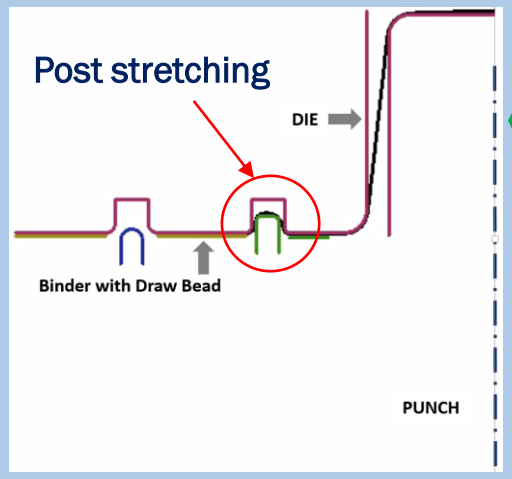
Stake Bead on Punch

(Animation)

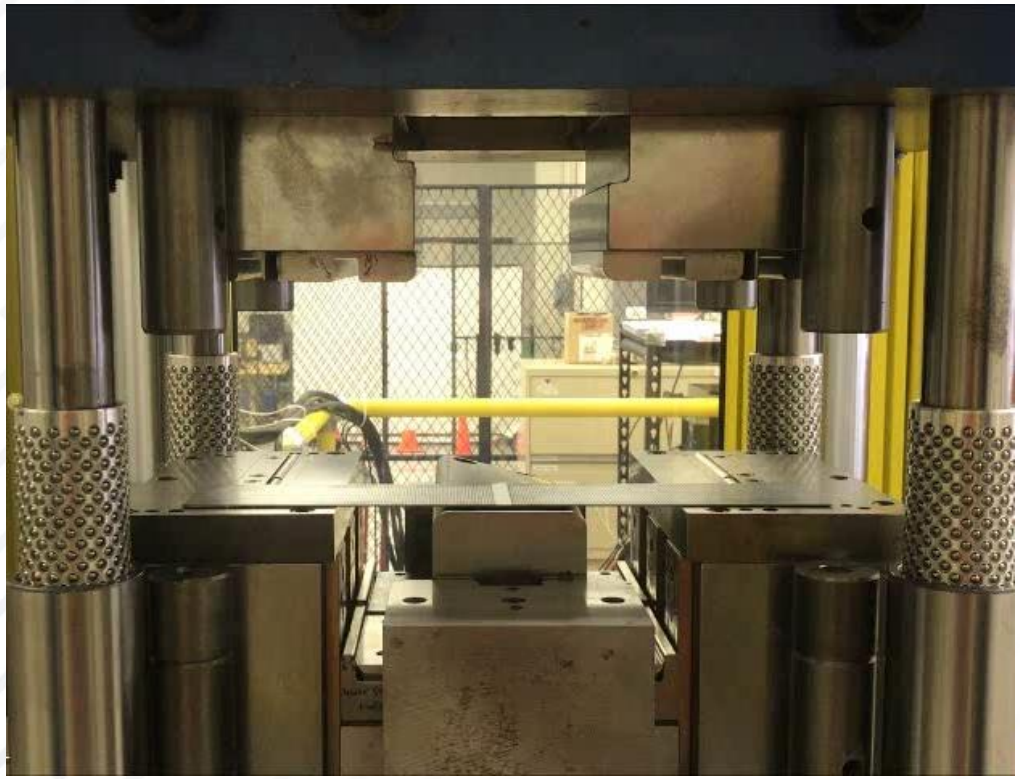








COMBINATION BEAD FORMING PROCESS



Binder Wrap

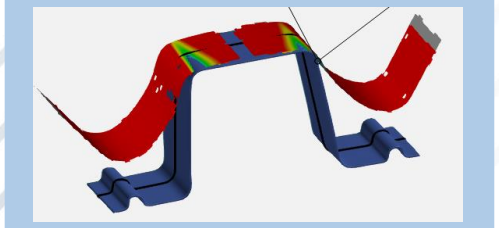
Forming

(Video)

EXPERIMENTAL TEST

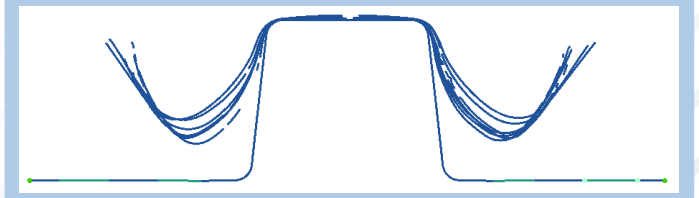
	Draw Bead 0.0 mm	Draw Bead 1.0 mm	Draw Bead 2.0 mm	Draw Bead 3.0 mm	Draw Bead 4.0 mm	Draw Bead 5.0 mm	Draw Bead 6.0 mm
Stake Bead: 0.0 mm							
Stake Bead: 4.6 mm							
Stake Bead: 5.6 mm							
Stake Bead: 6.6 mm							
Stake Bead: 7.6 mm							

Geometry Analysis of Argus



Sprung Geometries Export

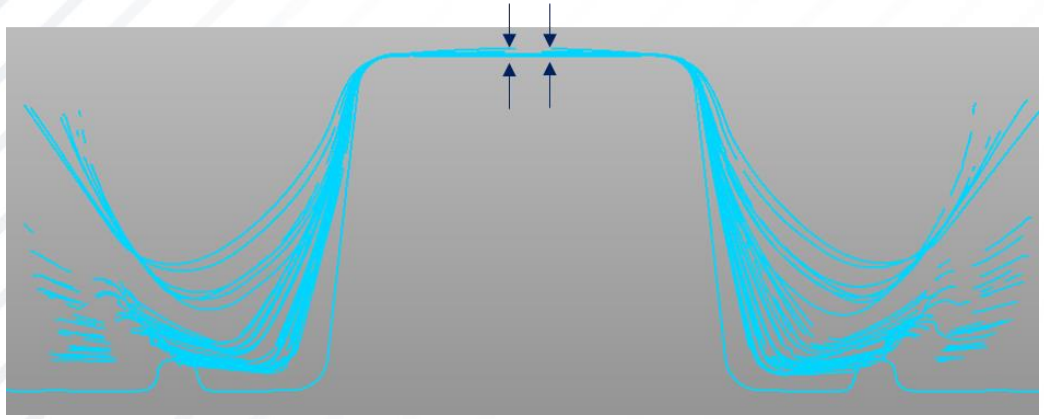
Geometries Layout



Springback Evaluation

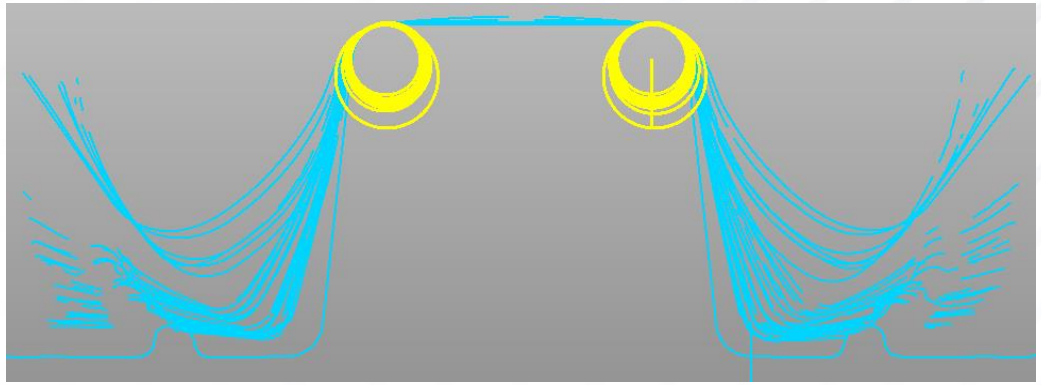
INDEXES FOR SPRINGBACK EVALUATION

Index 1: relaxed space of panel top



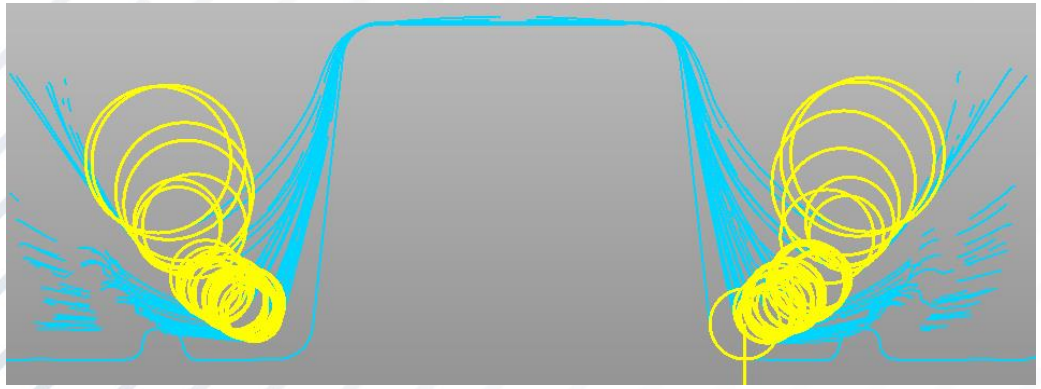
Index of relaxed space of panel top to define part tightness

Index 2: sprung ratio of punch radius



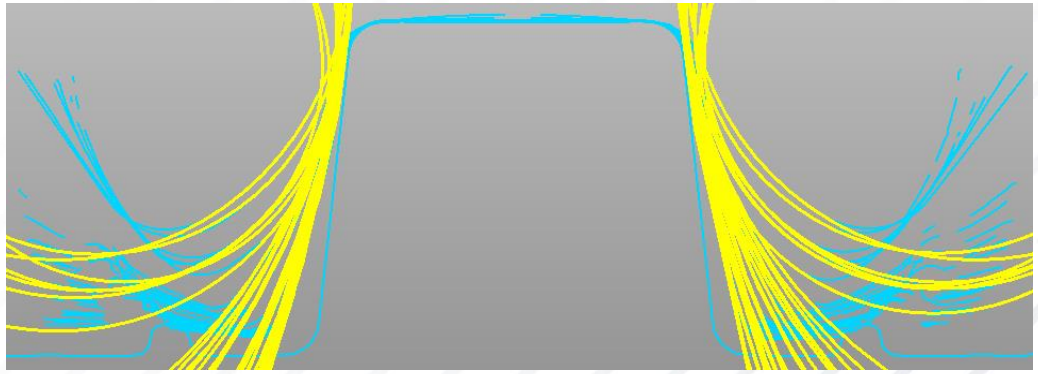
to define springback of side wall and top surface:
(R sprung – R target) / R target

Index 3: sprung ratio of die radius



to define springback between side wall and lower flange:
(R sprung – R target) / R target

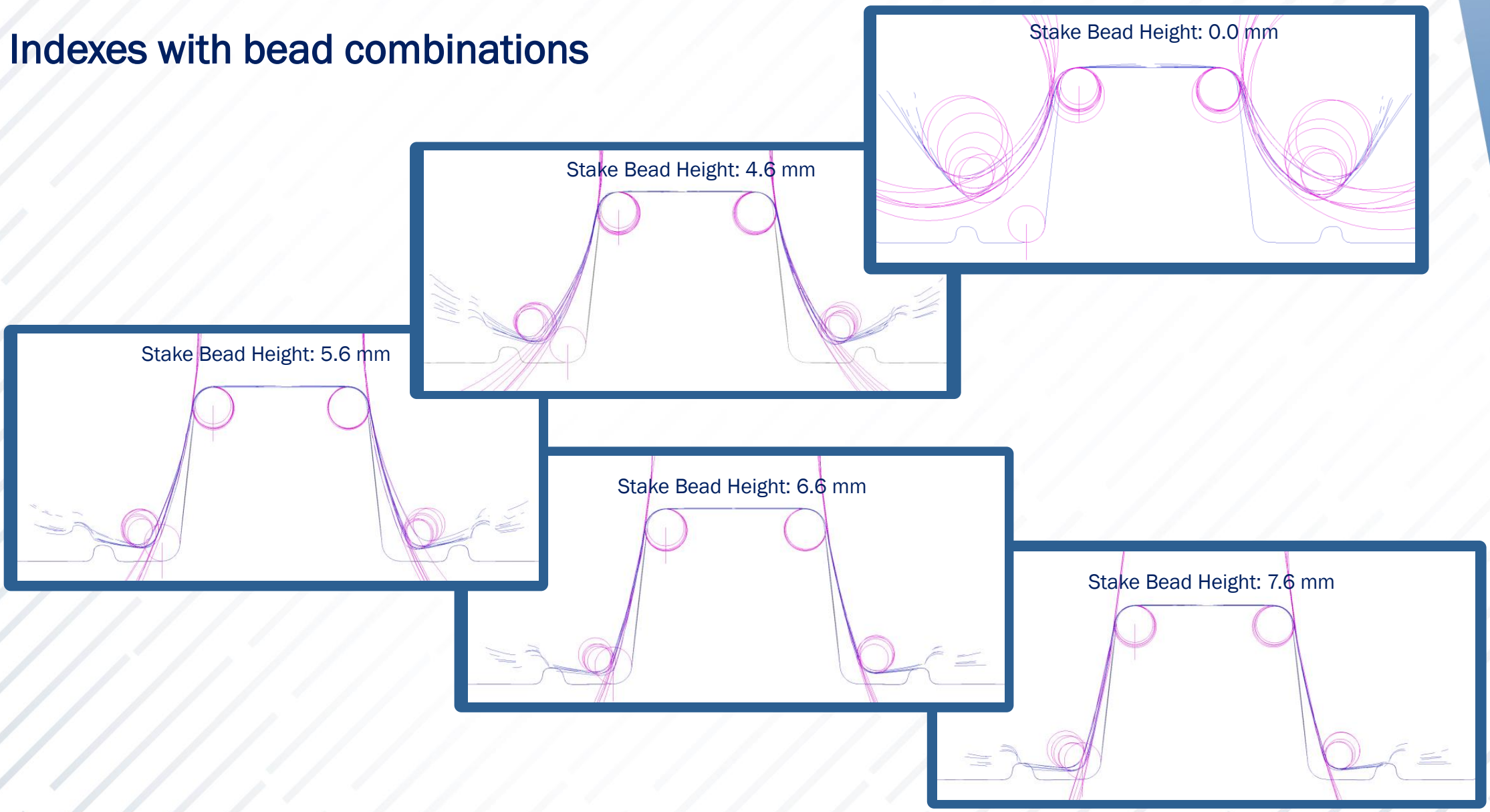
Index 4: side wall curvature



to characterize side wall curl degree:
1 / R sprung

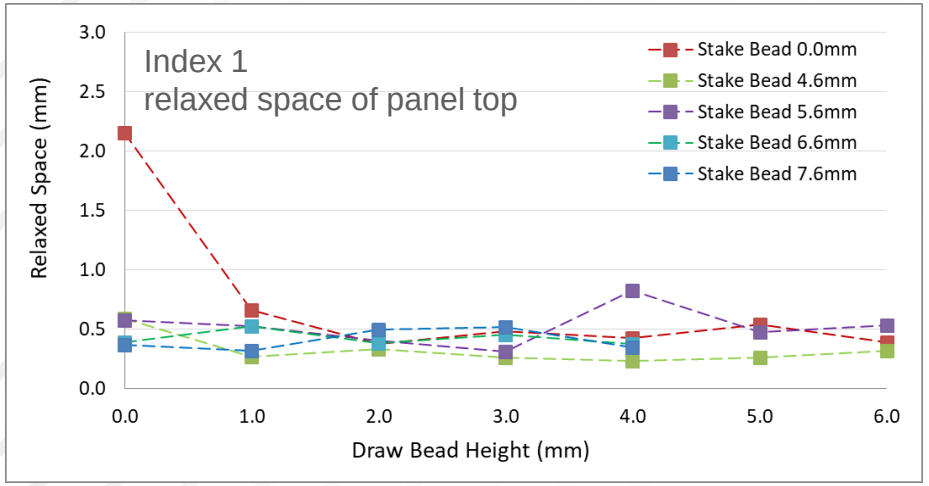
EXPERIMENTAL TEST RESULTS

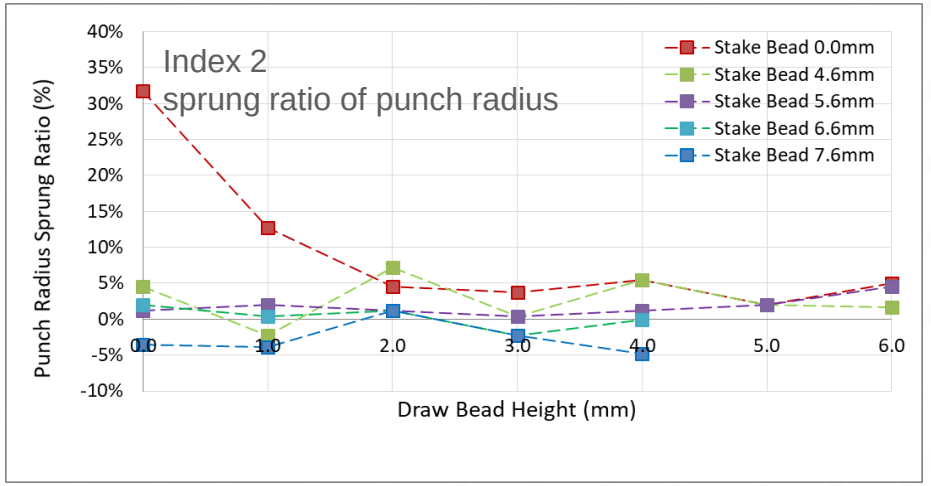
Indexes with bead combinations



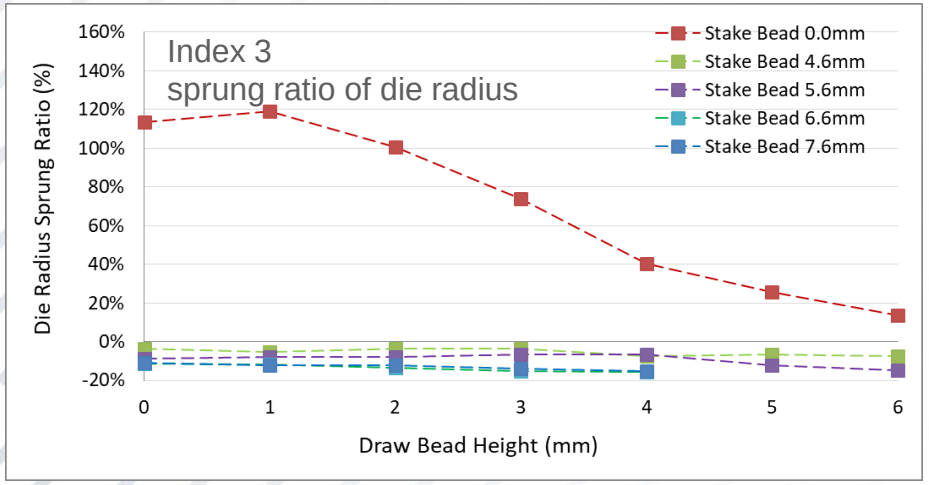
EXPERIMENTAL TEST RESULTS

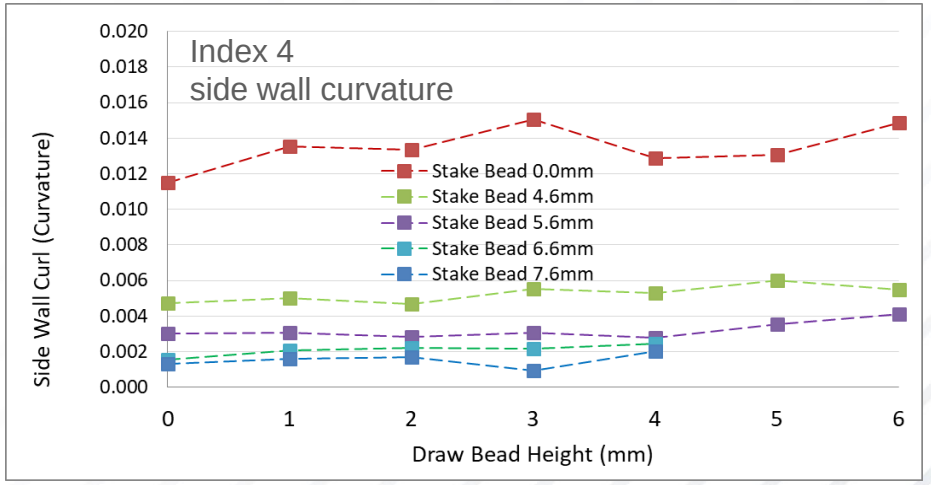
Draw Bead Impact to Springback





Without stake bead, draw bead reduces indexes of relax space of part top, sprung ratio of punch radius and sprung ratio of die radius, but makes side wall curl worse.

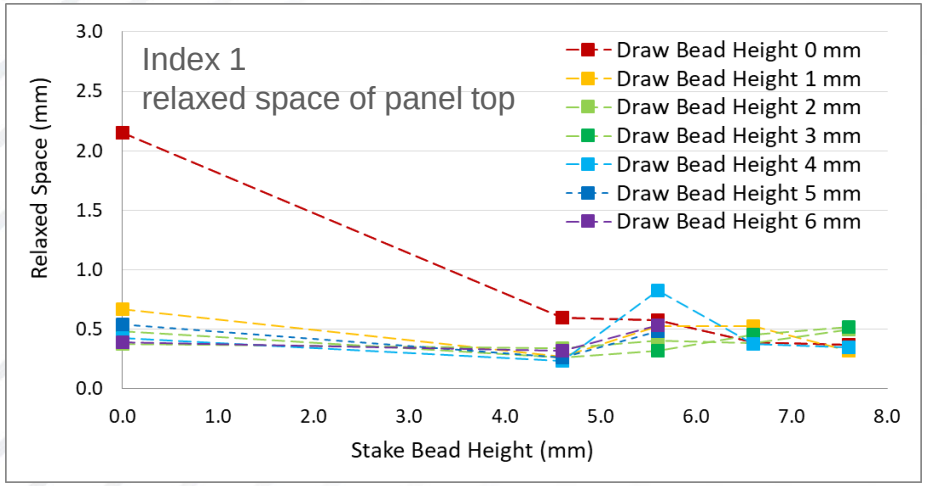


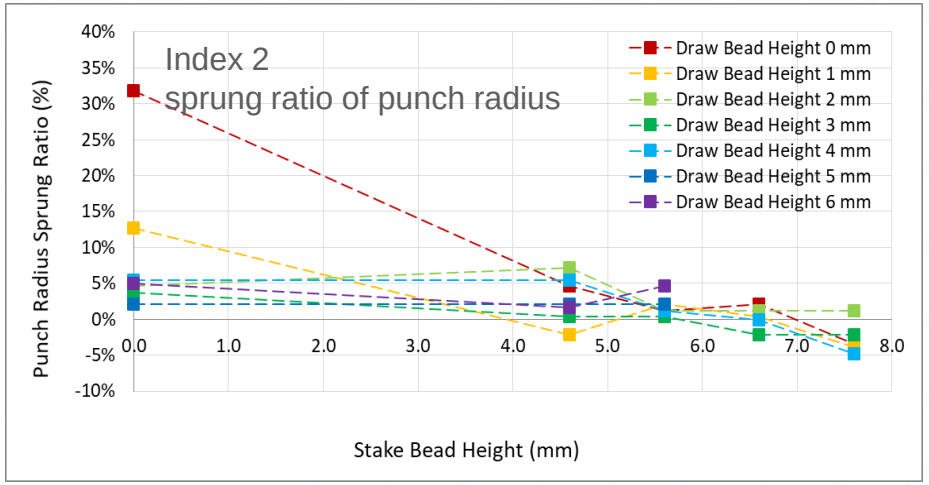


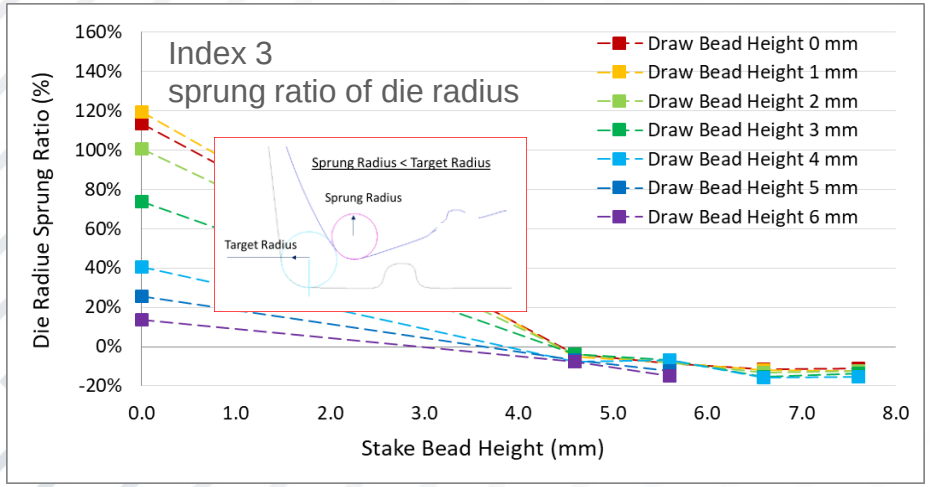
When the stake bead is engaged for post stretch, draw bead impacts less on springback control.

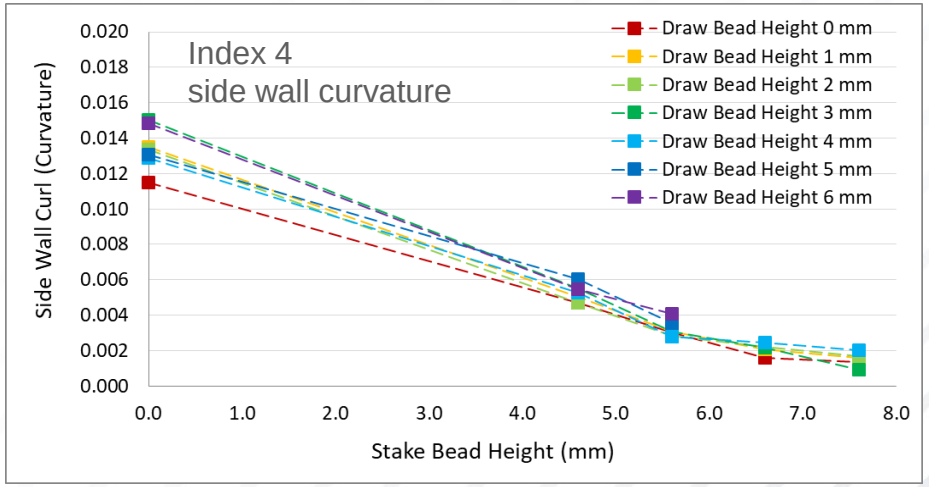
EXPERIMENTAL TEST RESULTS

Stake Bead Impact to Springback









Stake bead improves springback significantly on sprung ratio of punch radius and side wall curl, but not as much on relaxed space of part top and makes sprung ratio of die radius worse

SUMMARY OF EXPERIMENTAL STUDY

- Combined influence of draw and stake beads towards springback management was explored
- A novel approach, based on radius / curvature change, is proposed to quantify panel springback; each of the four indices is focused on a specific geometry feature of the panel
- Stress distribution across sheet thickness is closely related to springback; combination-bead can be used effectively to achieve stress equalization for springback control
- Because of the complexity of combination bead impacts, optimized bead combinations should be considered for springback control.
- Scale-up laboratory-scale study and develop springback control guidelines for effective control of springback in stamping production

VIRTUAL STUDY

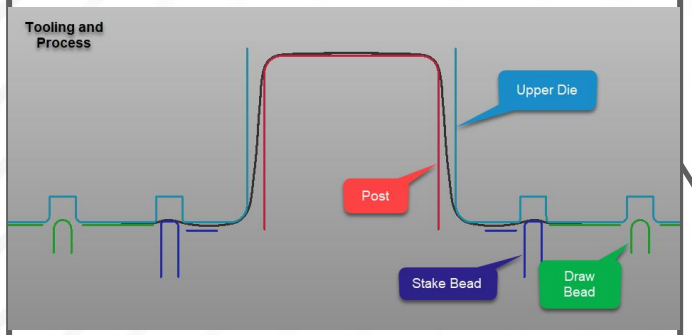
- Baseline Virtual to Physical outcomes

- Mechanical rationale for tryout observations
  - Panel shape response to bead changes?

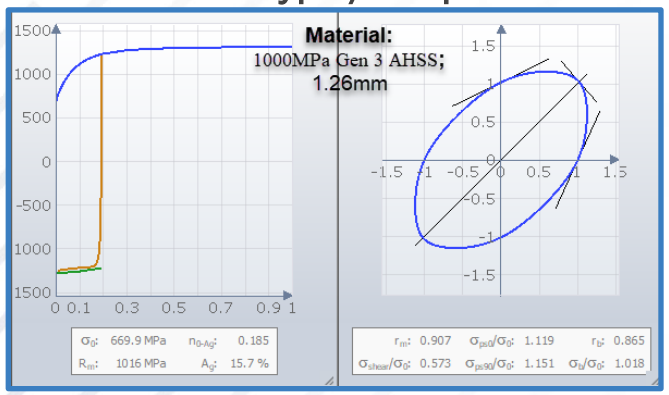
- Develop guidance for springback management

VIRTUAL STUDY

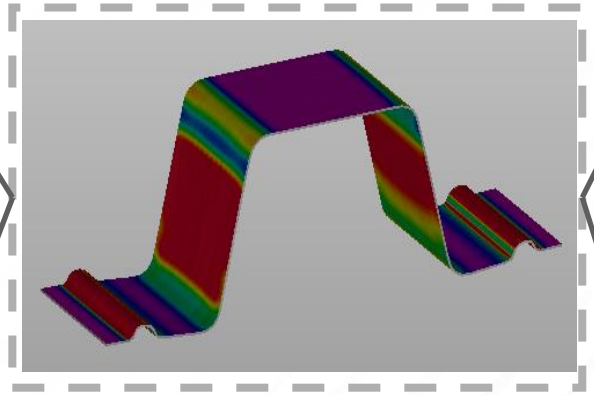
Die / Process Conditions



Material Type / Properties



Stamping Simulations



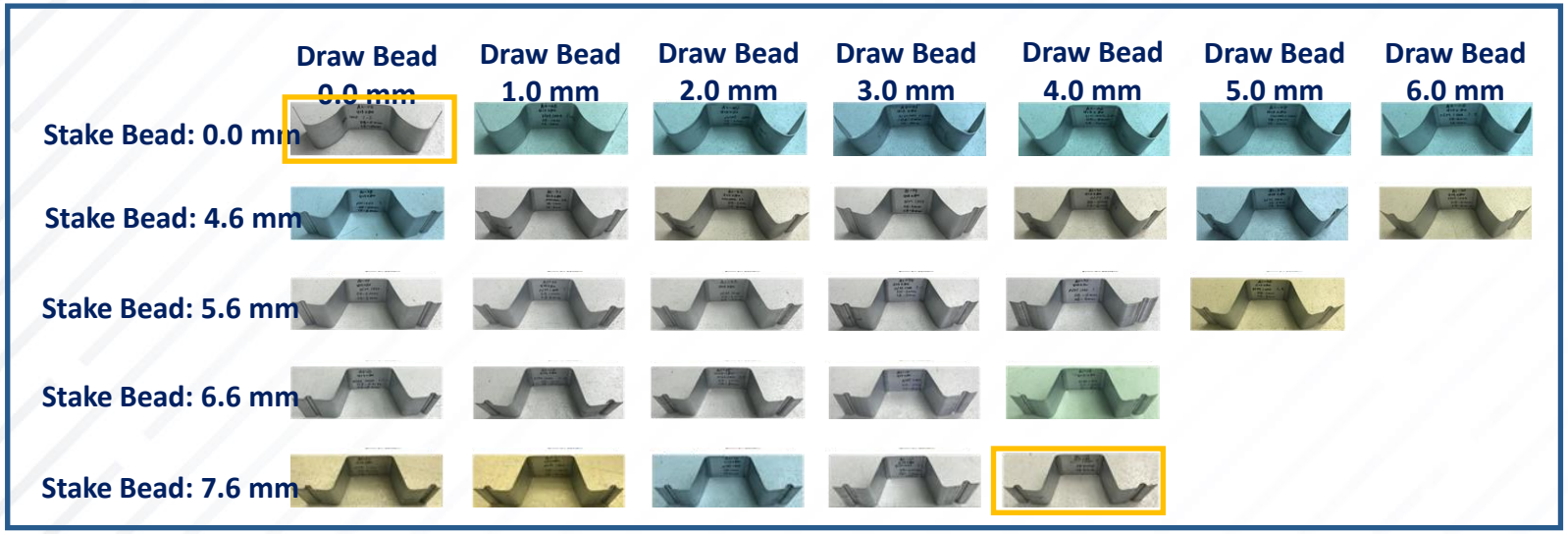
Tryout / Production Conditions

Friction / Tribology

μ

VIRTUAL STUDY

Baseline Virtual to Physical outcomes

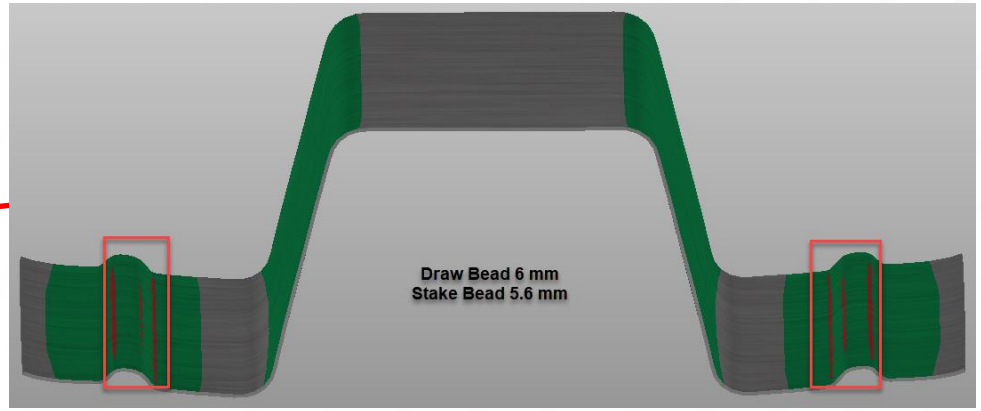


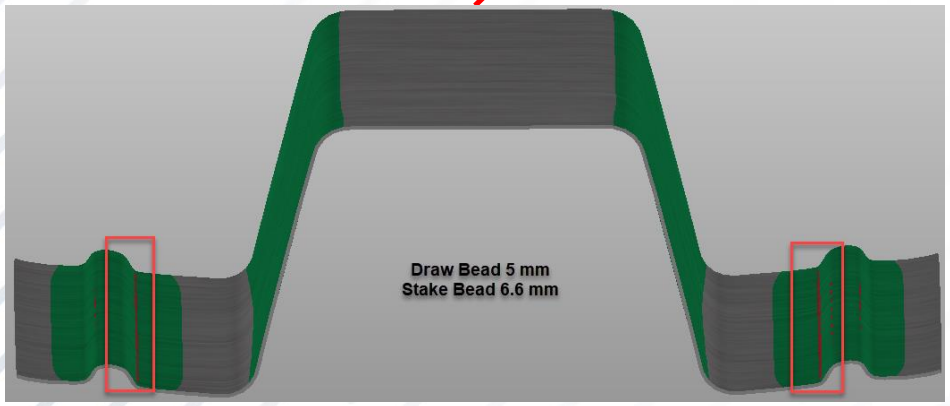
- Friction / Lube Conditions unknown
  - Virtual Reverse-engineering using highlighted tryout outcomes
  - 0.34

VIRTUAL STUDY

Baseline Virtual to Physical outcomes

Digital Overlay Sampling	0	1	2	3	4	5	6	Draw Bead Height (mm)
0							✓	
4.6	✓			✓				
5.6				✓		✓	✓	
6.6		✓				✓		
7.6	✓				✓			
Stake Bead Height (mm)	Intact / Scanned Panels					Split Panels		

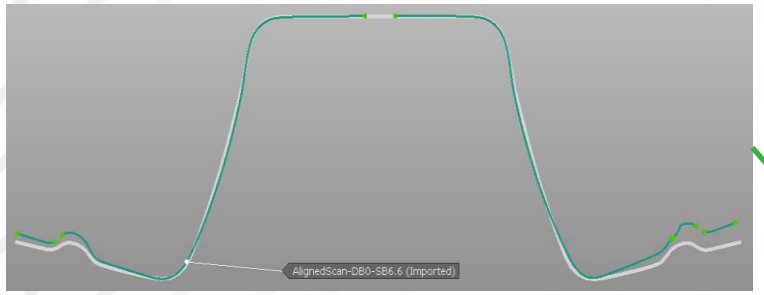


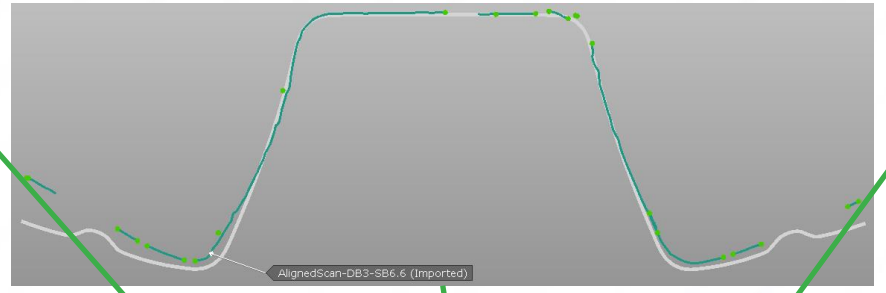


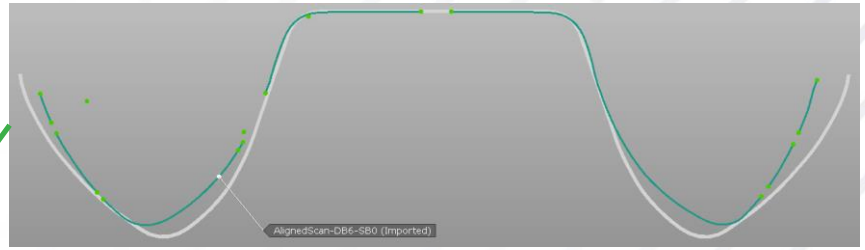
Combinations of large Draw Bead Height and Stake Bead Entry observed to split panel at Stake Bead

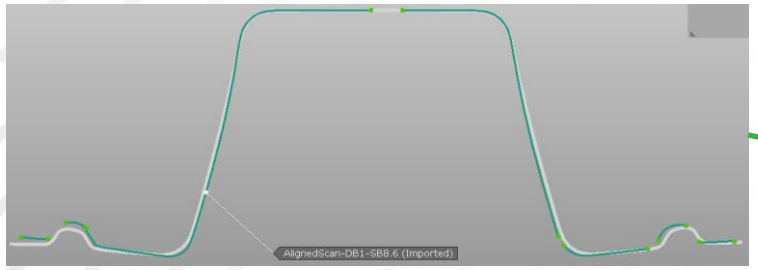
VIRTUAL STUDY

Baseline Virtual to Physical outcomes









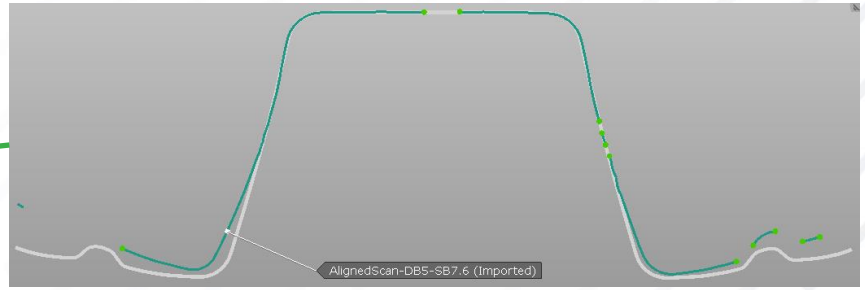
Digital Overlay Sampling	0	1	2	3	4	5	6
0							✓
4.6	✓			✓			
5.6				✓		✓	
6.6		✓				✓	
7.6	✓				✓		

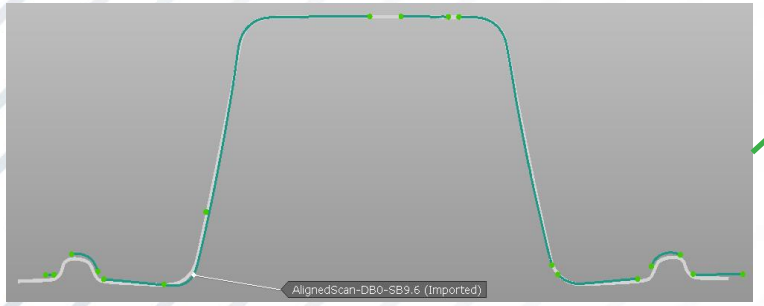
Draw Bead Height (mm)

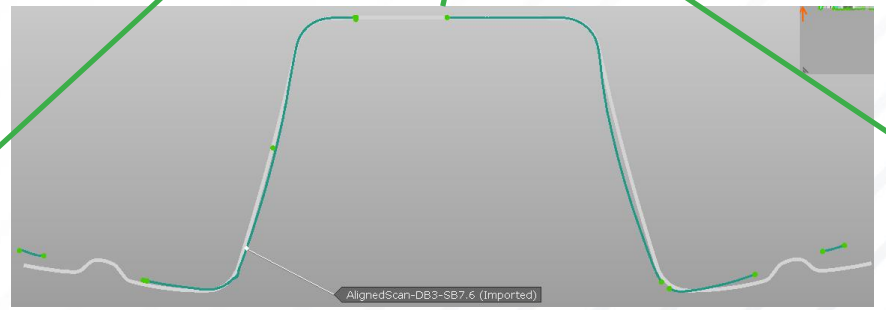
Stake Bead Height (mm)

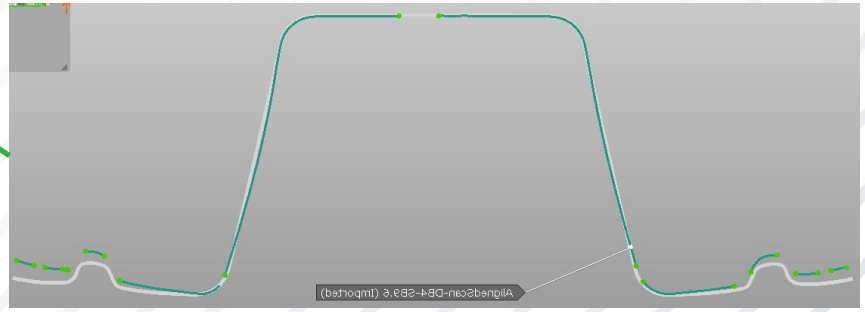
Intact / Scanned Panels

Split Panels





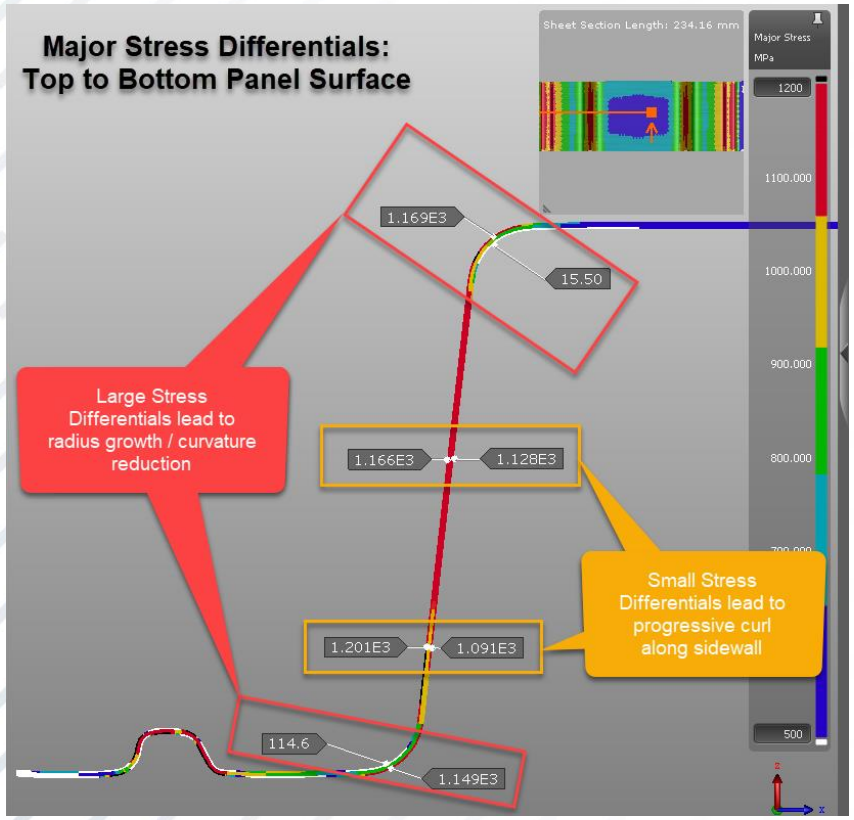


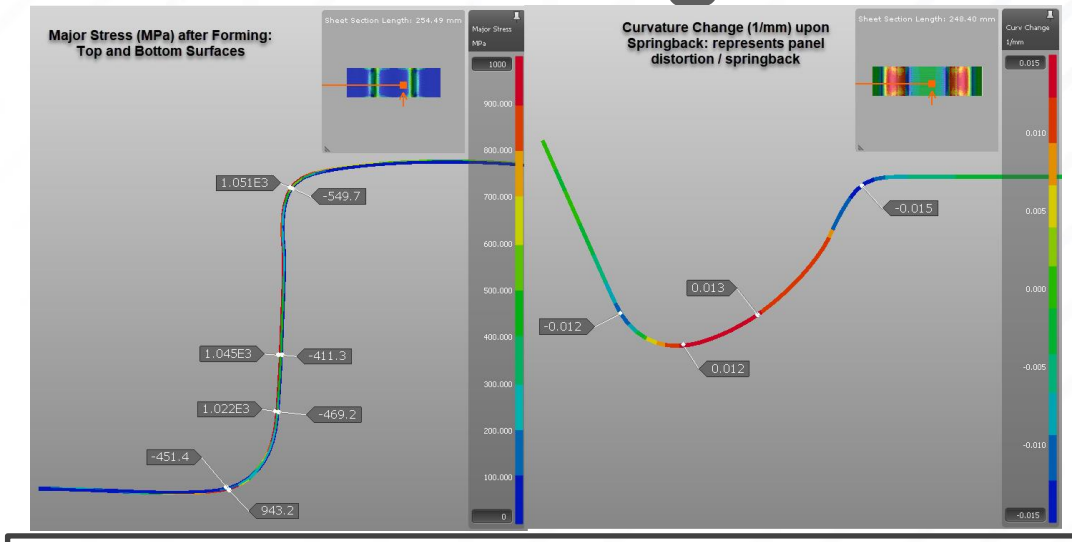


Sprung Panel Scans overlaid on Virtual Outcomes

VIRTUAL STUDY

Panel shape response to bead changes

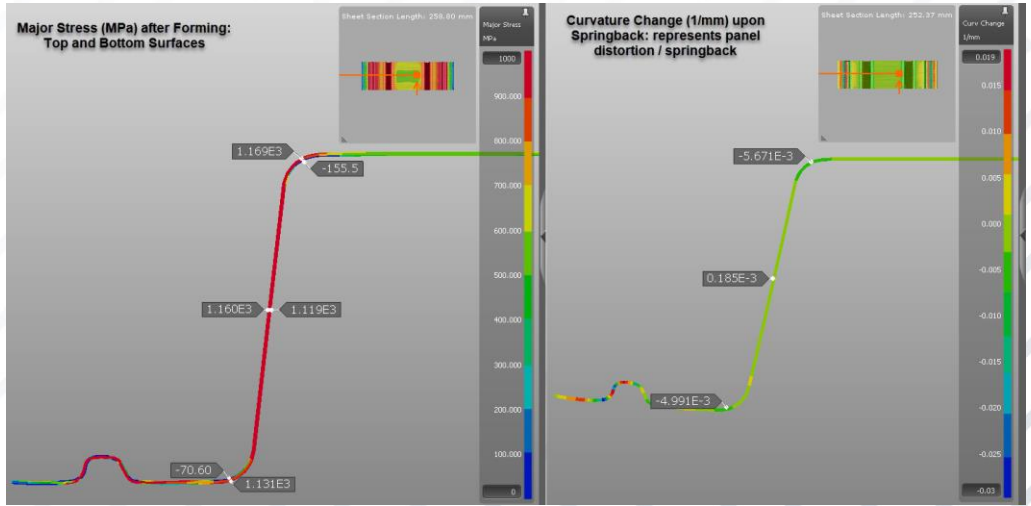




Draw Bead 0 mm, Stake Bead 0 mm:
lack of bead restraint leads to minimal panel stretch, and therefore to large panel distortion upon springback

Increased panel stretch reduces stress difference between top and bottom surfaces; this reduces panel distortion – curvature change – upon springback

Draw Bead 4 mm, Stake Bead 7.6 mm:
bead restraint leads to strong panel stretch, and therefore to reduced panel distortion upon springback



VIRTUAL STUDY

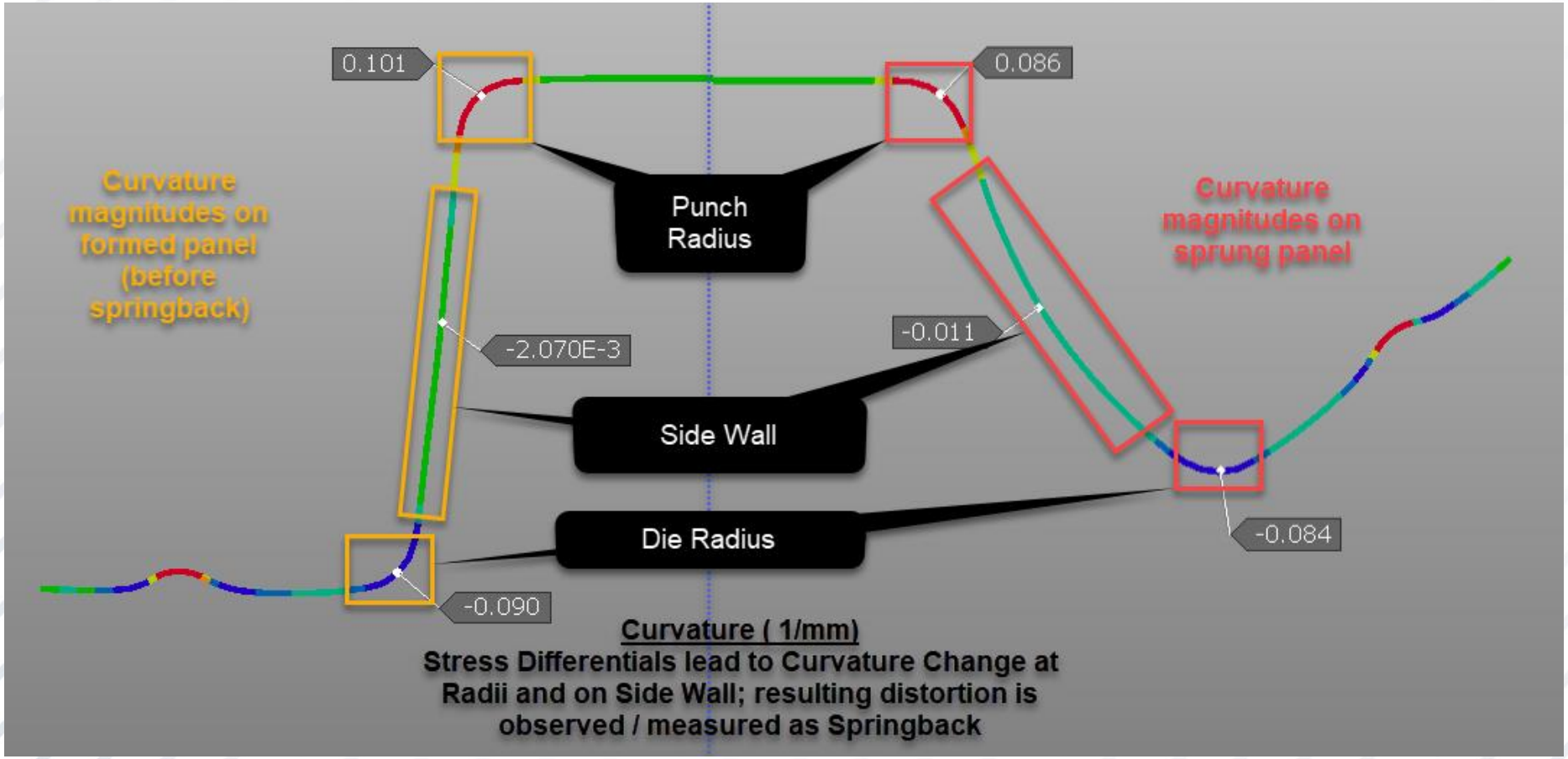
Guidance for Springback Management

- Optimal combination of Draw Bead and Stake Bead?
- Considerations from practical experience:
  - Stake Beads improve stretch => reduce springback
  - Draw Beads ensure stable process
- Metric for characterizing springback / panel distortion?

VIRTUAL STUDY

Guidance for Springback Management

- Metric for characterizing springback / panel distortion?



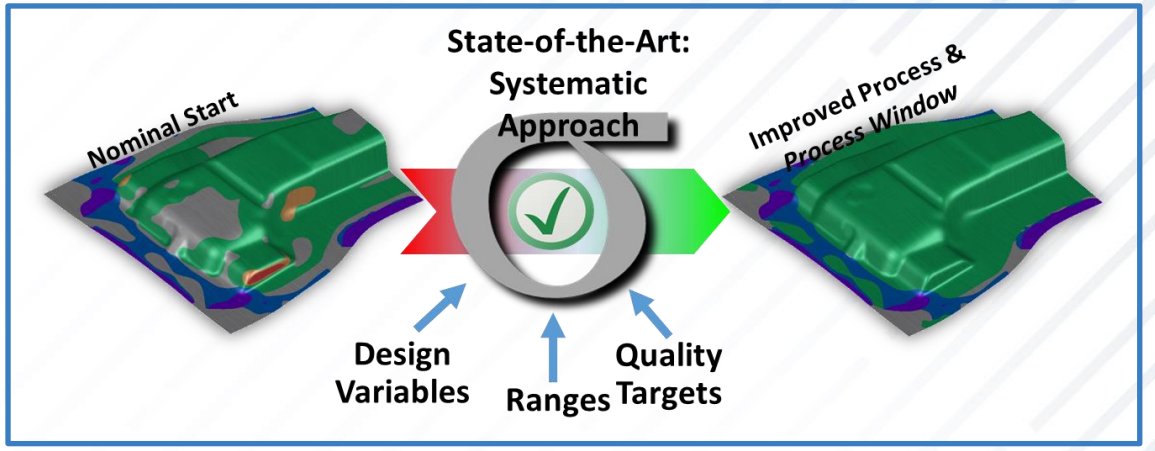
"Curvature Change" upon springback relaxation is an appropriate measure of panel distortion

VIRTUAL STUDY

Systematic Process Exploration

Explore full range of tooling / process

- Draw Bead 0-6 mm
- Stake Bead 0-7.6 mm



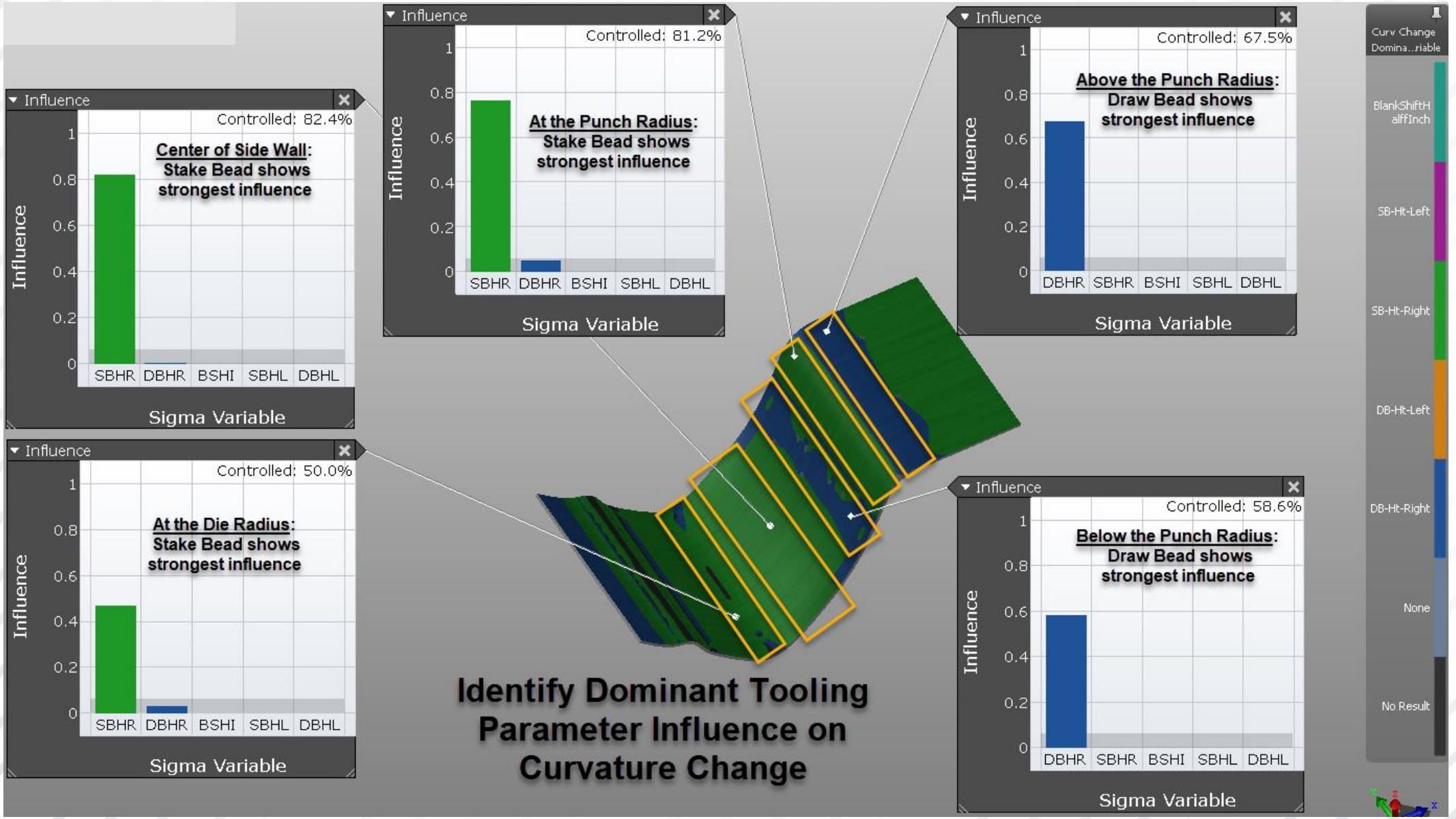
Define Quality Targets

- Minimize Curvature Changes
- Avoid Splits at Stake Bead

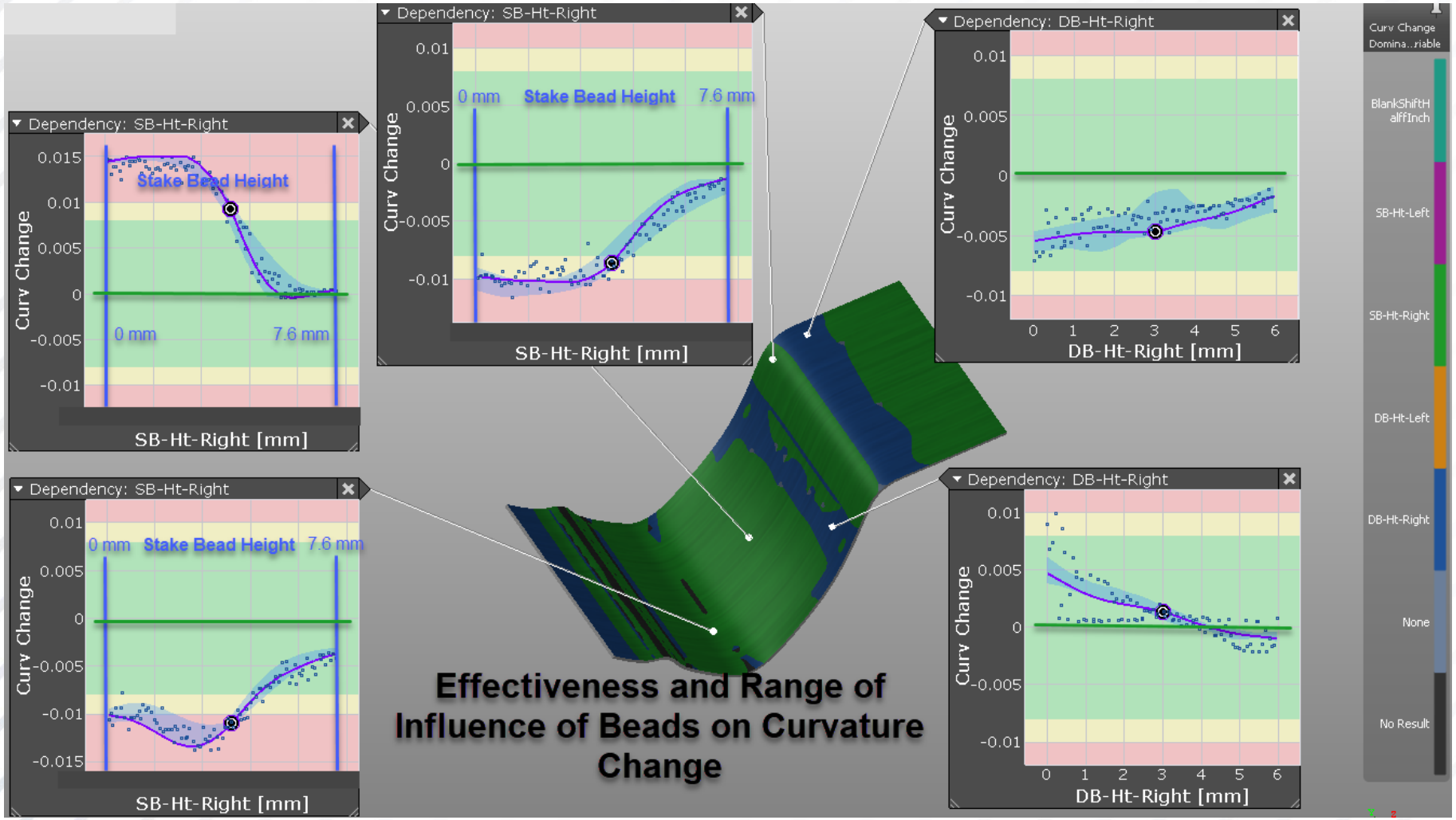
Identify process / tool settings for achieving Quality Targets

- *Automatic*
- Balanced, to accommodate conflicting Quality Targets
- Establish “process window” with acceptable results

VIRTUAL STUDY - OUTCOMES



VIRTUAL STUDY - OUTCOMES

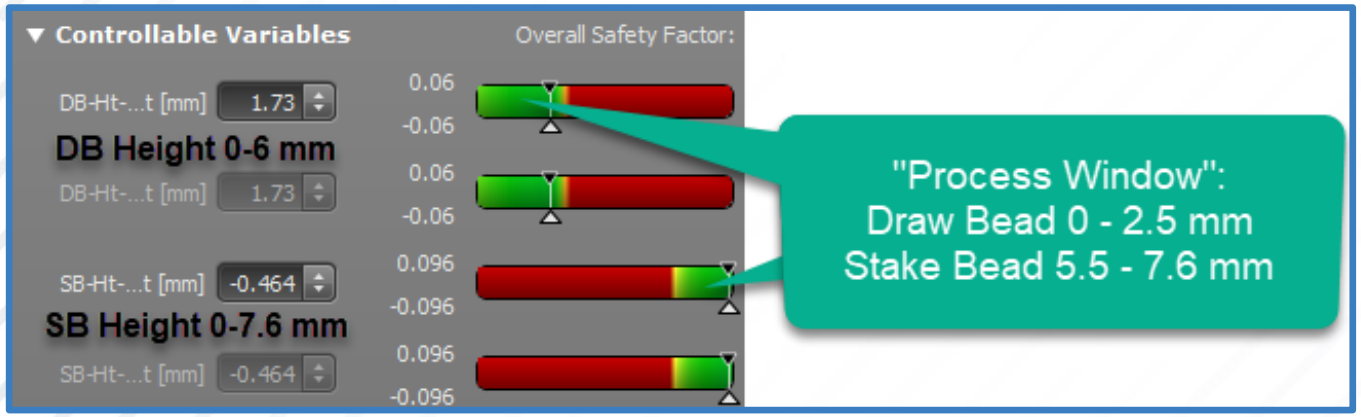


- As Stake Bead and / or Draw Bead height increases, panel Curvature Change is seen to approach 0, the **target line:** ——
- Stake Bead observed to be more effective than Draw Bead in achieving this target
- Effectiveness varies over Bead height ranges

VIRTUAL STUDY - OUTCOMES

Identify Solution Range => “Process Window”

- Reduced Springback
- Intact panel (no splits)



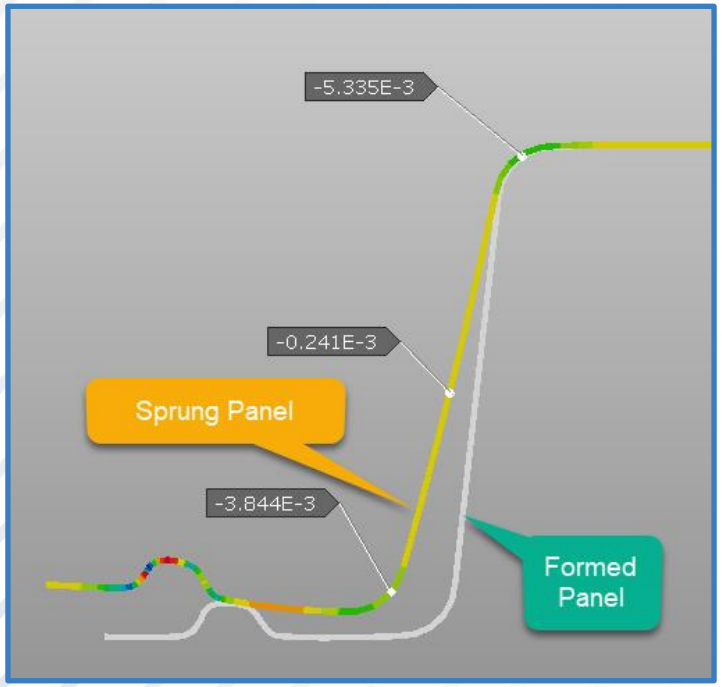
Green zones represent permissible range of Draw Bead and Stake Bead heights capable of producing “acceptable panels”: reduced springback, no splits

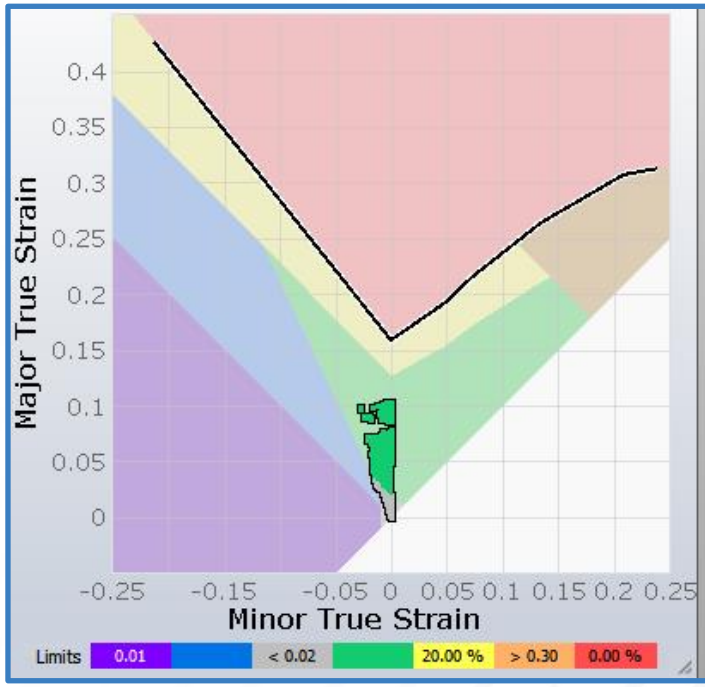
“Process Window” provides ranges of Draw and Stake Bead heights capable of producing acceptable panels; opportunity for trade off between these parameters

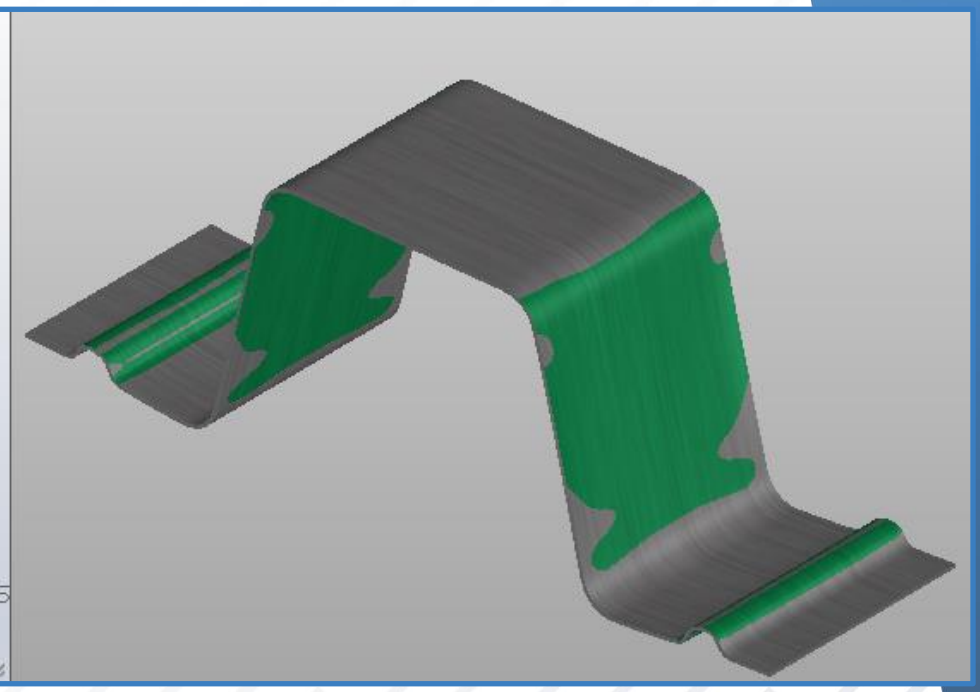
VIRTUAL STUDY - OUTCOMES

Validate a Solution within “Process Window”

- Draw Bead 2.5 mm, Stake Bead 6.5 mm
- Reduced Springback
- Intact panel (no splits)







Combination of Draw Bead Height 2.5 mm, and Stake Bead Height 6.5 mm reduces Curvature Change, and therefore minimizes panel distortion; this combination also avoids splits on the panel

SUMMARY OF VIRTUAL STUDY

- Material, Process, and Tooling conditions were diligently represented
  - Unknown Friction conditions were reverse-engineered
- Virtual outcomes were reliably baselined to physical panel observations
- Mechanical rationale provided for panel shape / distortion response to changes in tooling – draw bead and stake bead height
- Systematic Virtual Study carried out:
  - Desired outcomes – quality targets – were defined upfront
  - Full range of controllable tooling parameters was explored
  - Outcomes:
    - Range of Draw Bead and Stake Bead heights over which springback can be mitigated: “Process Window”
    - Draw Bead 2.5 mm and Stake Bead 6.5 mm represents a viable solution within this Process Window, and was virtually validated

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THANK YOU!

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