

# GREAT DESIGNS IN **STEEL**

## **STRETCH BENDABILITY EVALUATION OF MONOLITHIC AND LASER WELDED BLANKS**

Sobhan Nazari Tiji

Cleveland-Cliffs Inc. / Advanced Applications Engineer

# CONTENTS

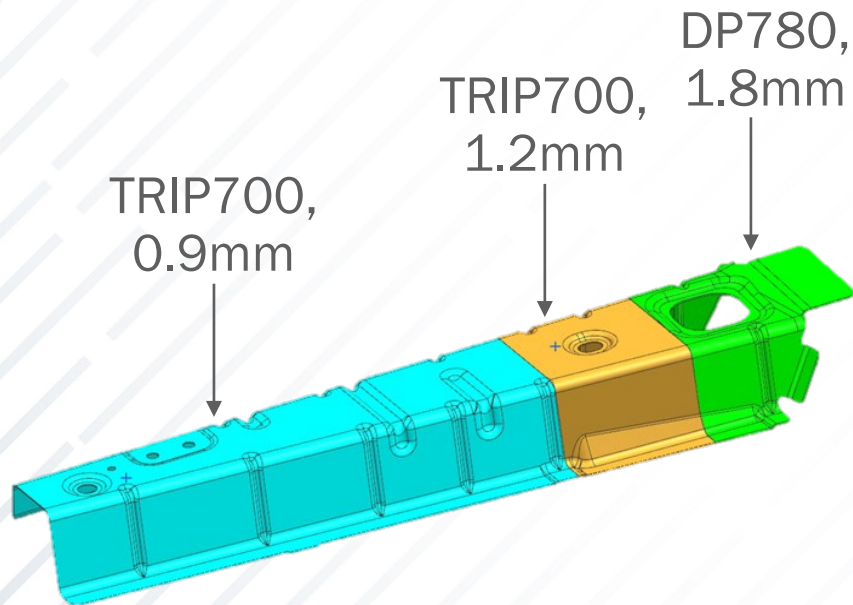
- Background
- Die concept design for the simulative testing
- Experimental setup; Testing procedure
- Stretch-bendability characterization method
- Stretch-bendability of 3<sup>rd</sup> Gen 1180, 1.2mm samples- monolithic and TWB

# BACKGROUND – STELLANTIS / TWB JOINT PROJECT

Product: Load Beam Outer Upper R&L

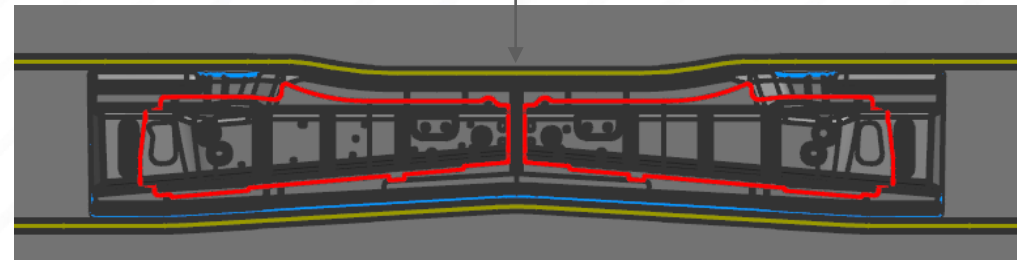
Tailor Welded Blank:

- ❑ 2 material grades: TRIP700, DP780
- ❑ 3 thicknesses: 0.9mm, 1.2mm, 1.8mm



Product

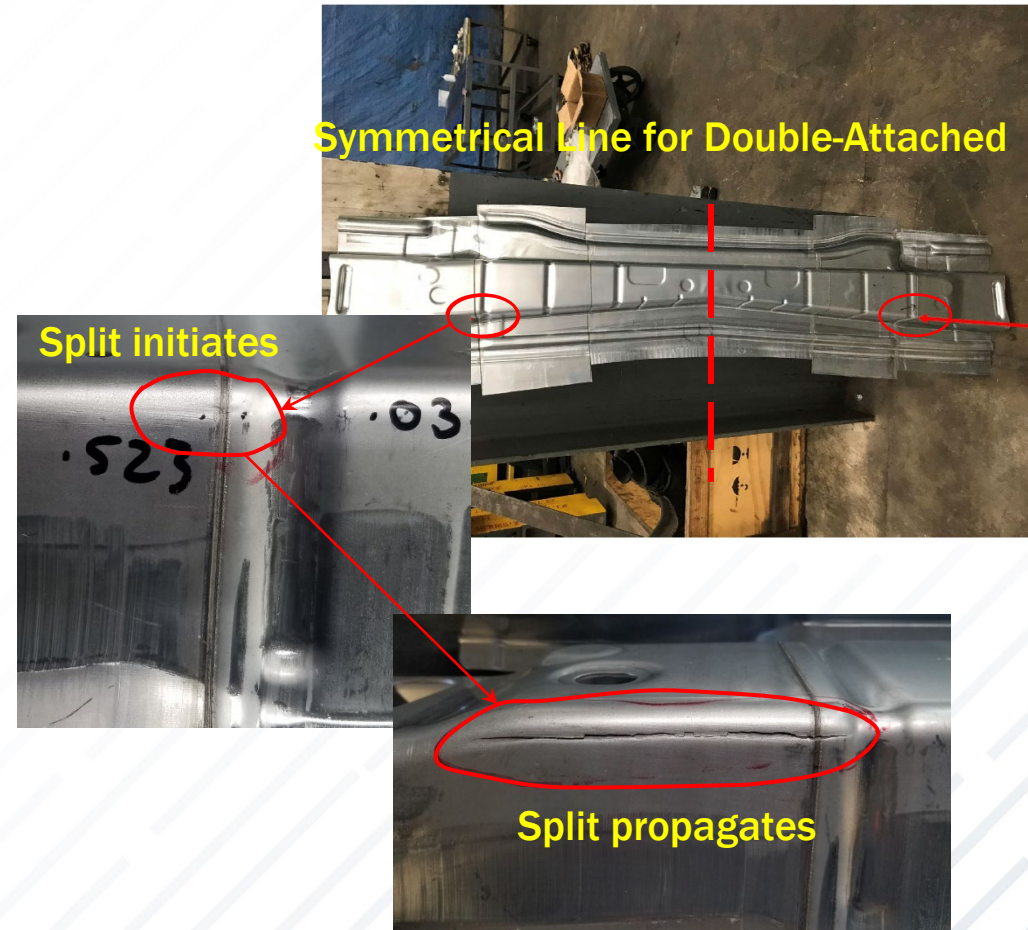
Stake bead for post-stretching on springback control



Die Setup for Double-Attached

# BACKGROUND – STAMPING ISSUE

- The crack in the red box under punch shoulder radius is a typical “stretch-bending” failure.
- This type of failure cannot be characterized by free bending (i.e. V bending/3-point bending) only.



# BACKGROUND

- Splitting resolved:
  - ❑ The tolerances of the incoming blank were tightened and gaging of the weld was improved to keep the weld in a more consistent location.

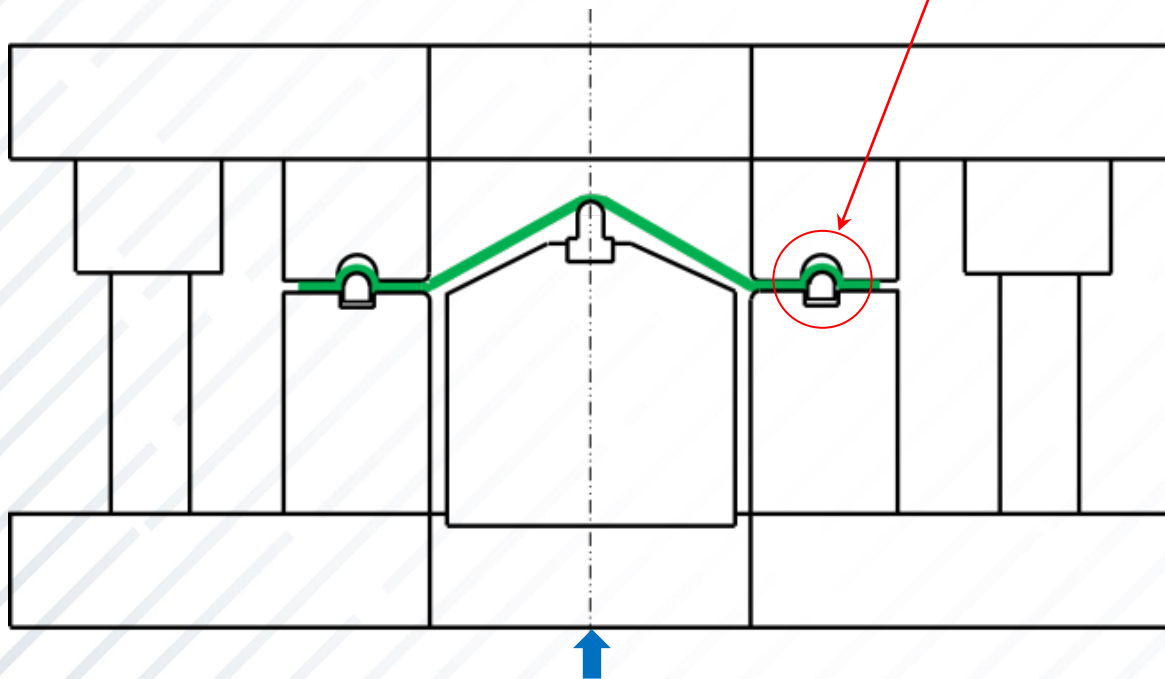


Successfully stamped product

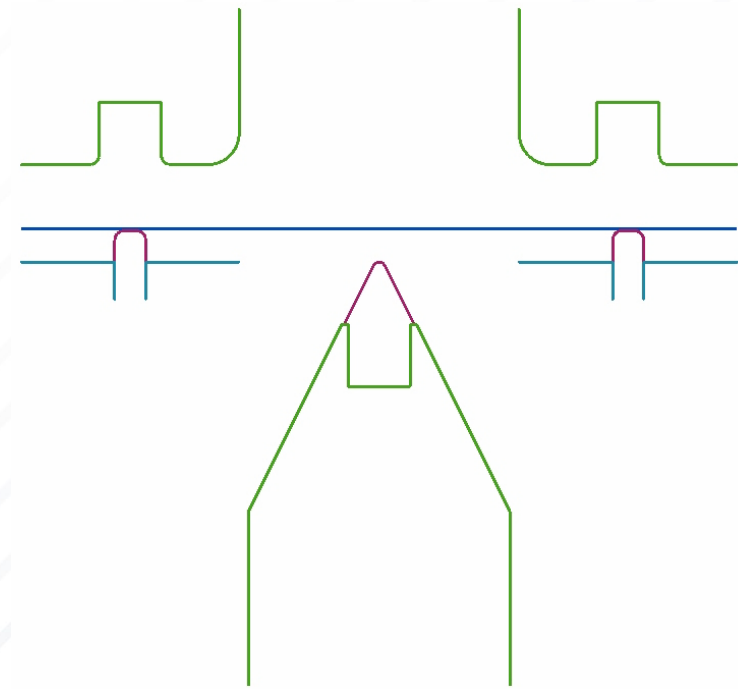
# LAB SCALED DIE FOR STRETCH BENDING INVESTIGATION

➤ Experimental test concept

Sample fully locked during bending



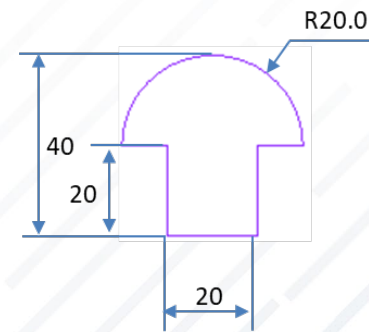
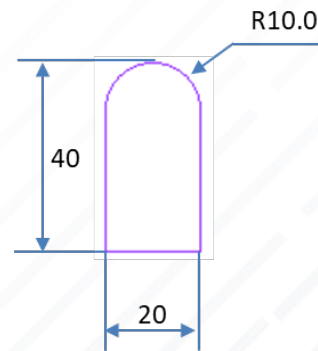
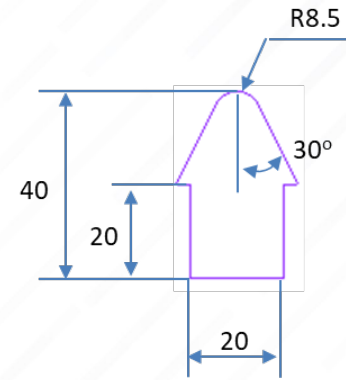
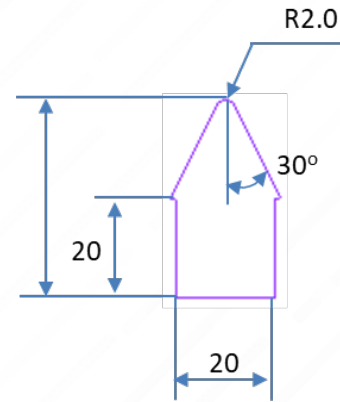
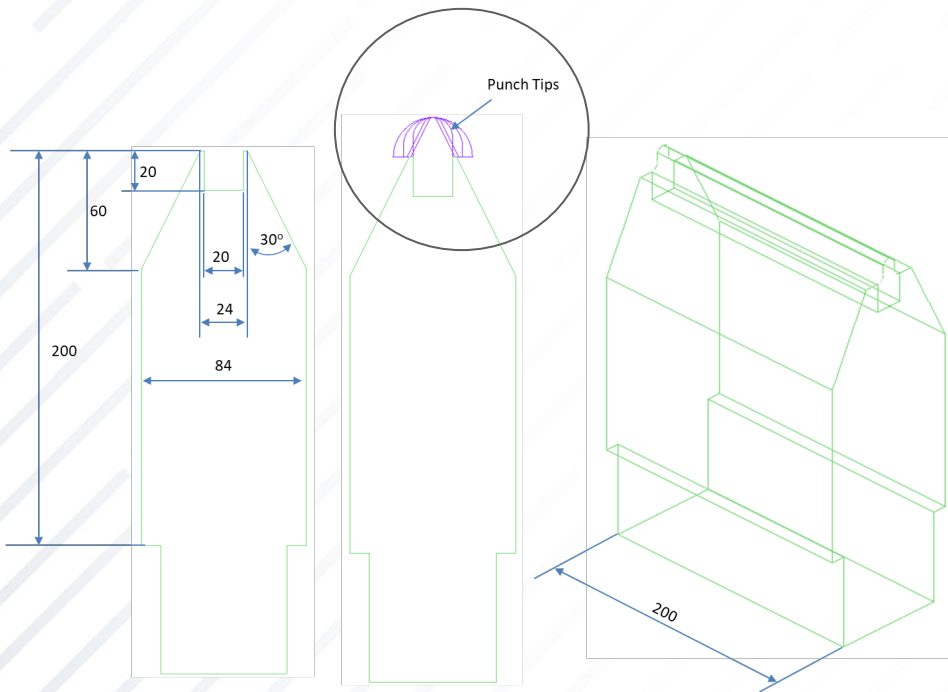
The process is bending under stretching



Animation for Stretch-Bending

# LAB SCALED DIE FOR STRETCH BENDING

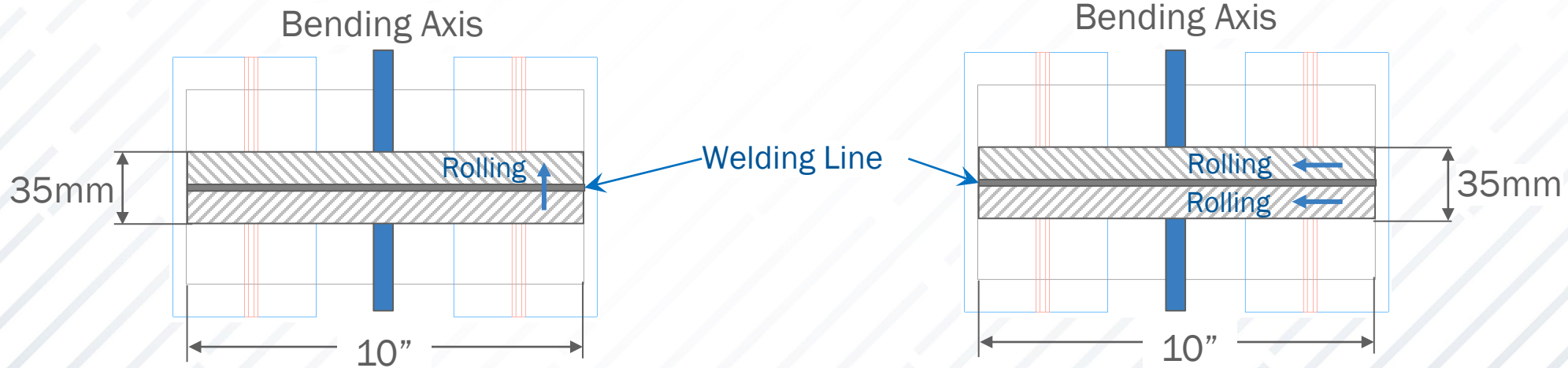
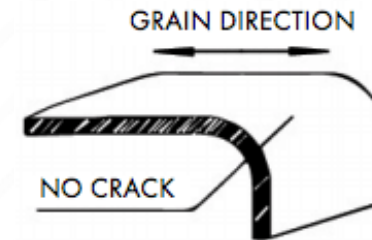
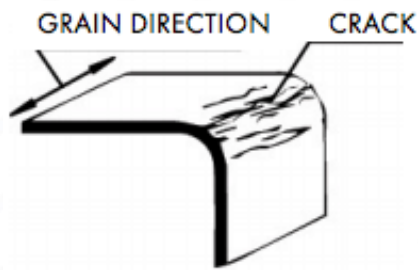
➤ Bending radii for multiple R/t



Total 14 punch radius designed for different 14 R over t ratio  
R2.0, R2.8, R3.6, R4.2, R4.8, R5.0, R5.5, R6.5, R7.5, R8.5, R10, R12.5, R15, R20

# TESTING SAMPLE FOR LAB SCALED STRETCH BENDING TEST

➤ Tailor Welded Blank

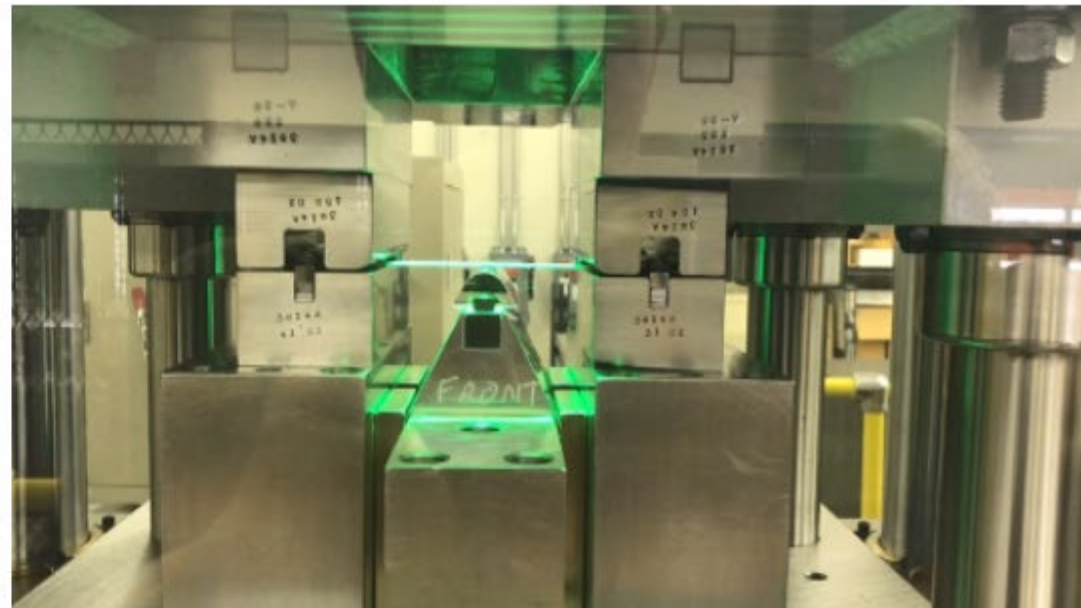


# STRETCH BENDING PROCESS WITH LAB SCALED DIE

Binder Closes To Ensure Sample is Fully Locked During Bending



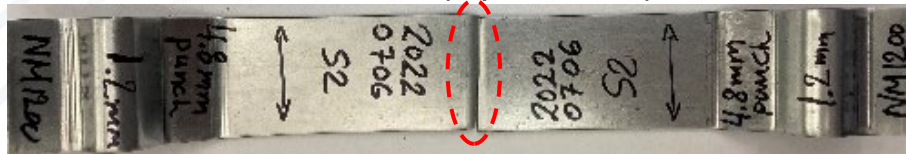
Punch Moves up for Stretch Bending



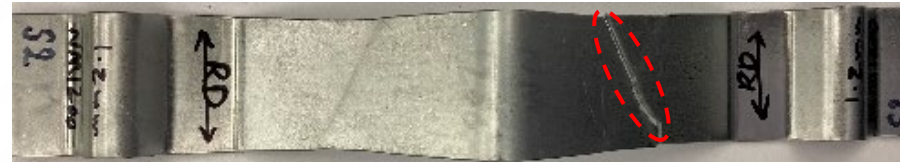
# FAILURE MODE

➤ Tested Samples & DIC Measured Strain Map

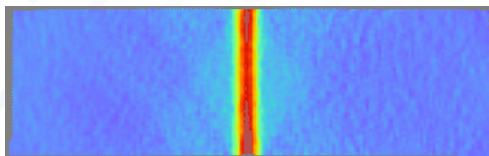
Tested Sample at punch radius of 4.2mm (R/T=3.5)



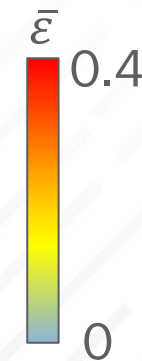
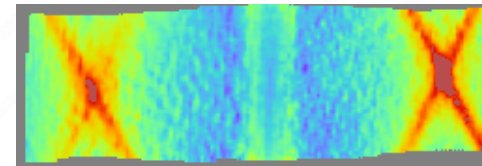
Tested Sample at punch radius of 10.0mm (R/T=8.3)



Effective Strain measured by DIC



Effective Strain measured by DIC

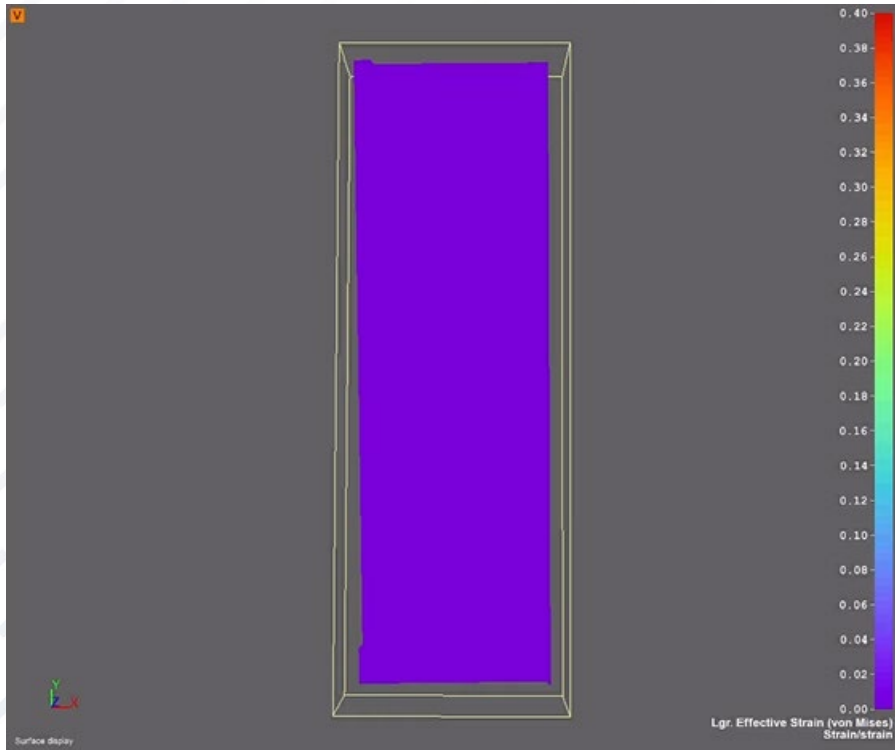


The narrow blank (254mm×35mm) is the optimized geometry to prevent pre-mature failure

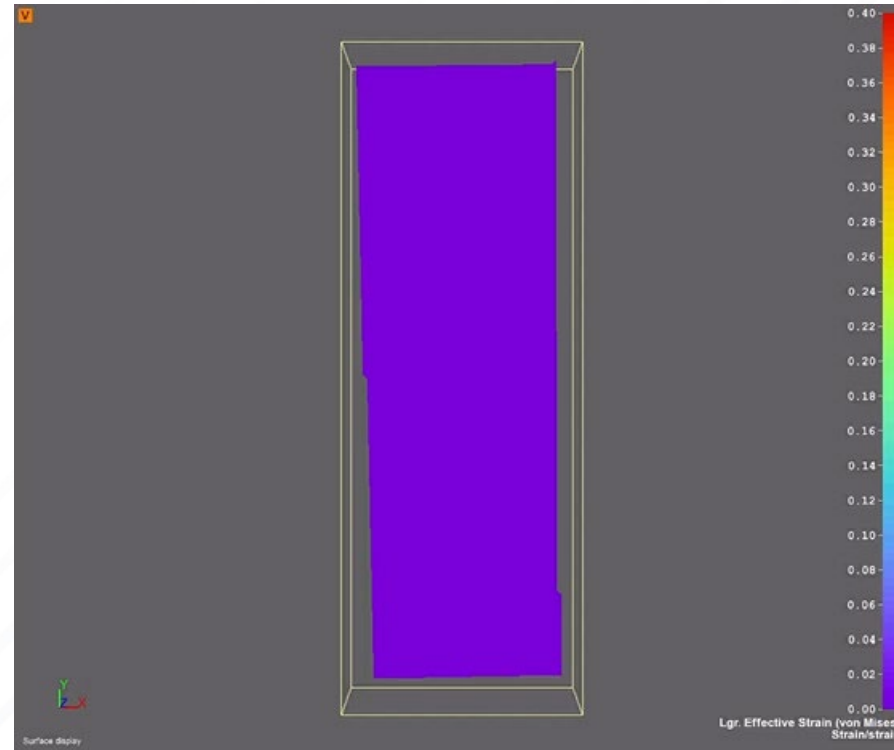
# FAILURE MODE

## ➤ DIC Results- Effective Strain Map

Ridge failure ( $R/t=3.5$ )



Sidewall failure ( $R/t=7.1$ )

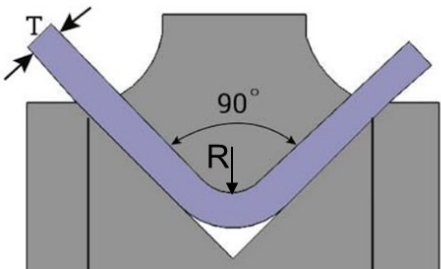


# STRETCH BENDING EVALUATION – BENDABILITY INDEX (B.I.)

Bendability Index (B.I.):  $B.I. = \frac{\alpha_B}{\alpha_T}$

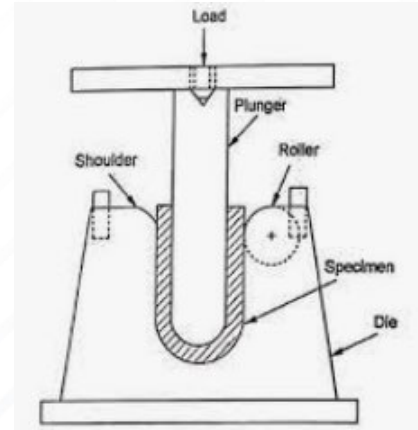
$\alpha_T$ : Target angle  
 $\alpha_B$ : Bending angle

V-Block Bending (Air Bending)



Target Angle  $\alpha_T$ :  $90^\circ$   
 Bending Angle  $\alpha_B$ :  $90^\circ$   
 $B.I. = \frac{\alpha_B}{\alpha_T} = \frac{90}{90} \% = 100\%$   
 To pursue the minimum R/t ratio with 100% of B.I.

ASTM E190 Guided Bending Test



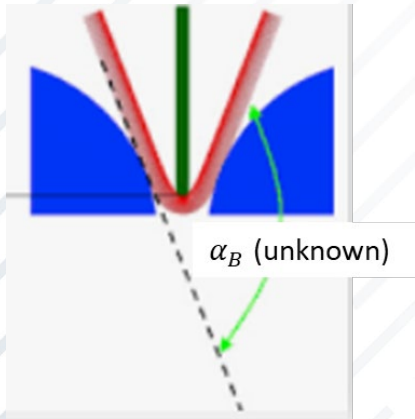
Target Angle  $\alpha_T$ :  $180^\circ$   
 Bending Angle  $\alpha_B$ :  $180^\circ$   
 $B.I. = \frac{\alpha_B}{\alpha_T} = \frac{180}{180} \% = 100\%$   
 To pursue the minimum R/t ratio with 100% of B.I.

# STRETCH BENDING EVALUATION – BENDABILITY INDEX (B.I.)

Bendability Index (B.I.):  $B.I. = \frac{\alpha_B}{\alpha_T}$

$\alpha_T$ : Target angle  
 $\alpha_B$ : Bending angle

## VDA (3-point) Bending

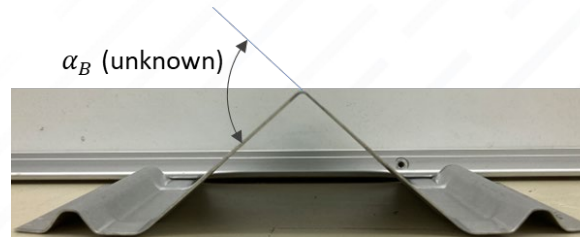


Target Angle  $\alpha_T$ : 180°  
 Bending Angle  $\alpha_B$ :  
 unknown

$$B.I. = \frac{\alpha_B}{\alpha_T} = \frac{?}{180} \% = ? \%$$

To pursue the maximum B.I. with fixed R/t ratio

## Stretch Bending



Target Angle  $\alpha_T$ : 90°  
 Bending Angle  $\alpha_B$ :  
 unknown

$$B.I. = \frac{\alpha_B}{\alpha_T} = \frac{?}{90} \% = ? \%$$

To pursue the maximum B.I. with fixed R/t ratio



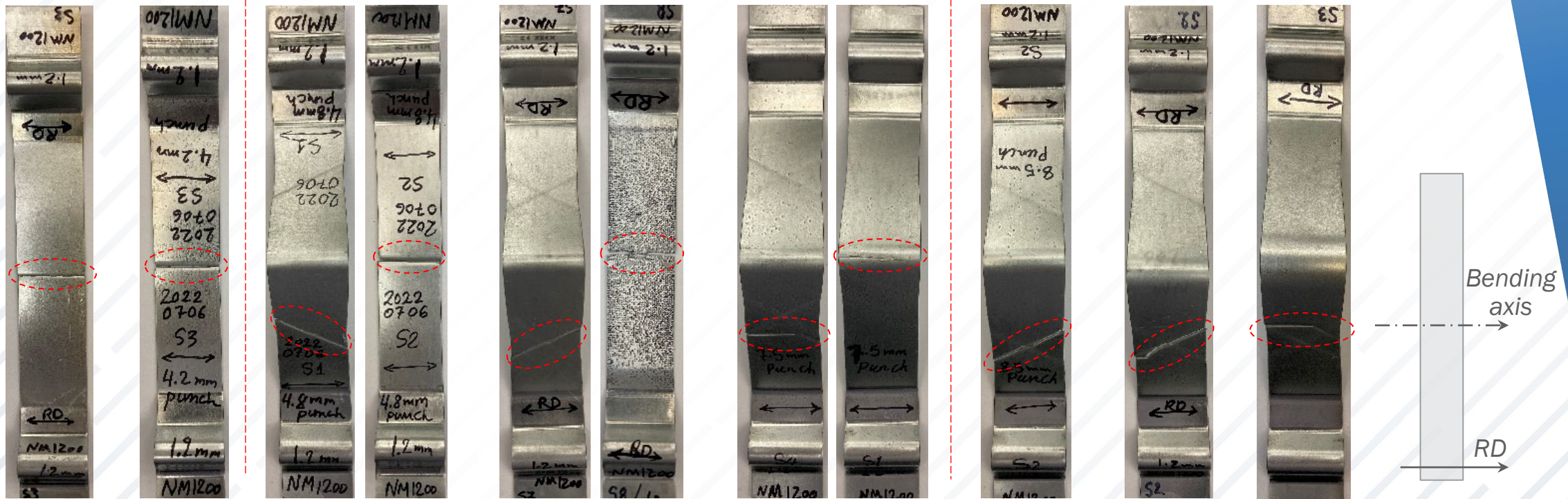
# STRETCH BENDING EXPERIMENT – 3<sup>RD</sup> GEN 1180 (1.2MM)- MONOLITHIC

## ➤ Tested Samples

Failure at punch ridge

Mix modes (failure at either punch ridge or sidewall)

Failure at sidewall



R=2mm R=4.2mm  
(R/t=0.8) (R/t=3.5)

R=4.8mm  
(R/t=4)

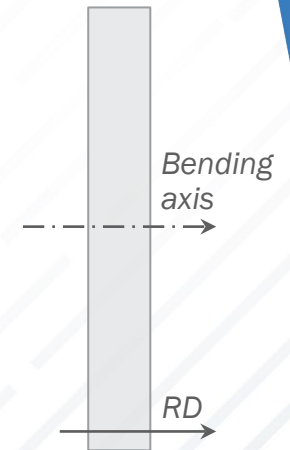
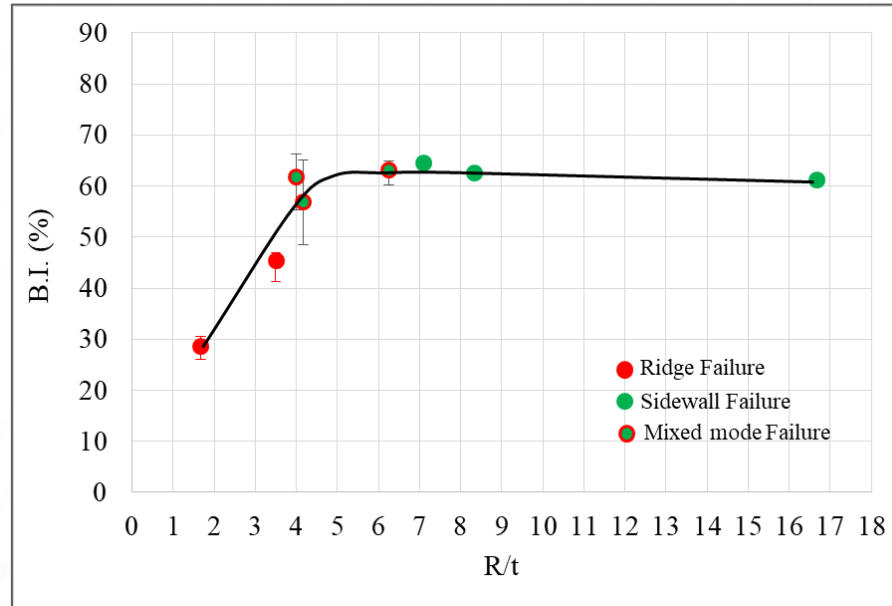
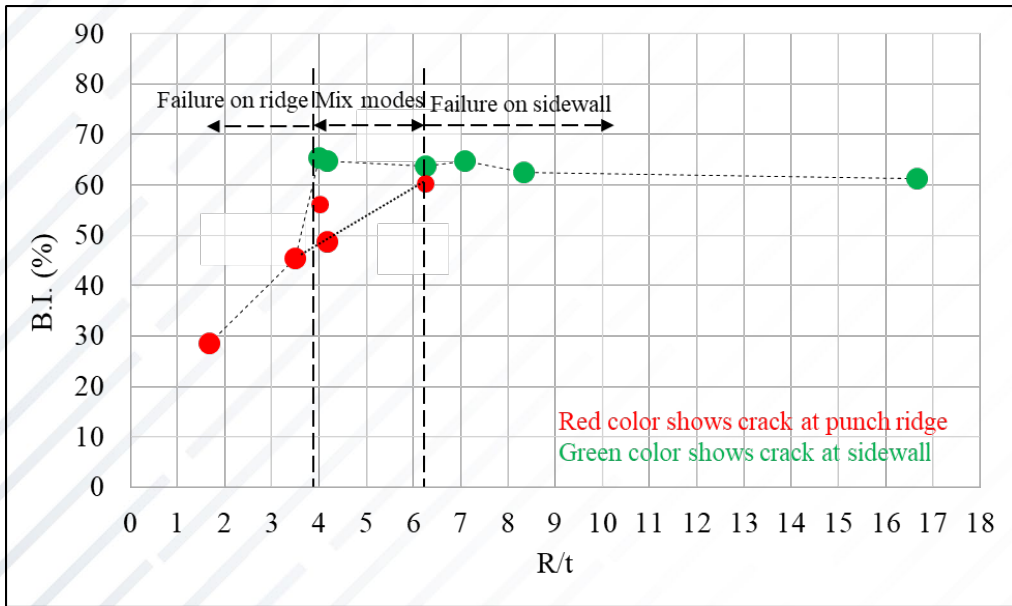
R=5mm  
(R/t=4.17)

R=7.5mm  
(R/t=6.25)

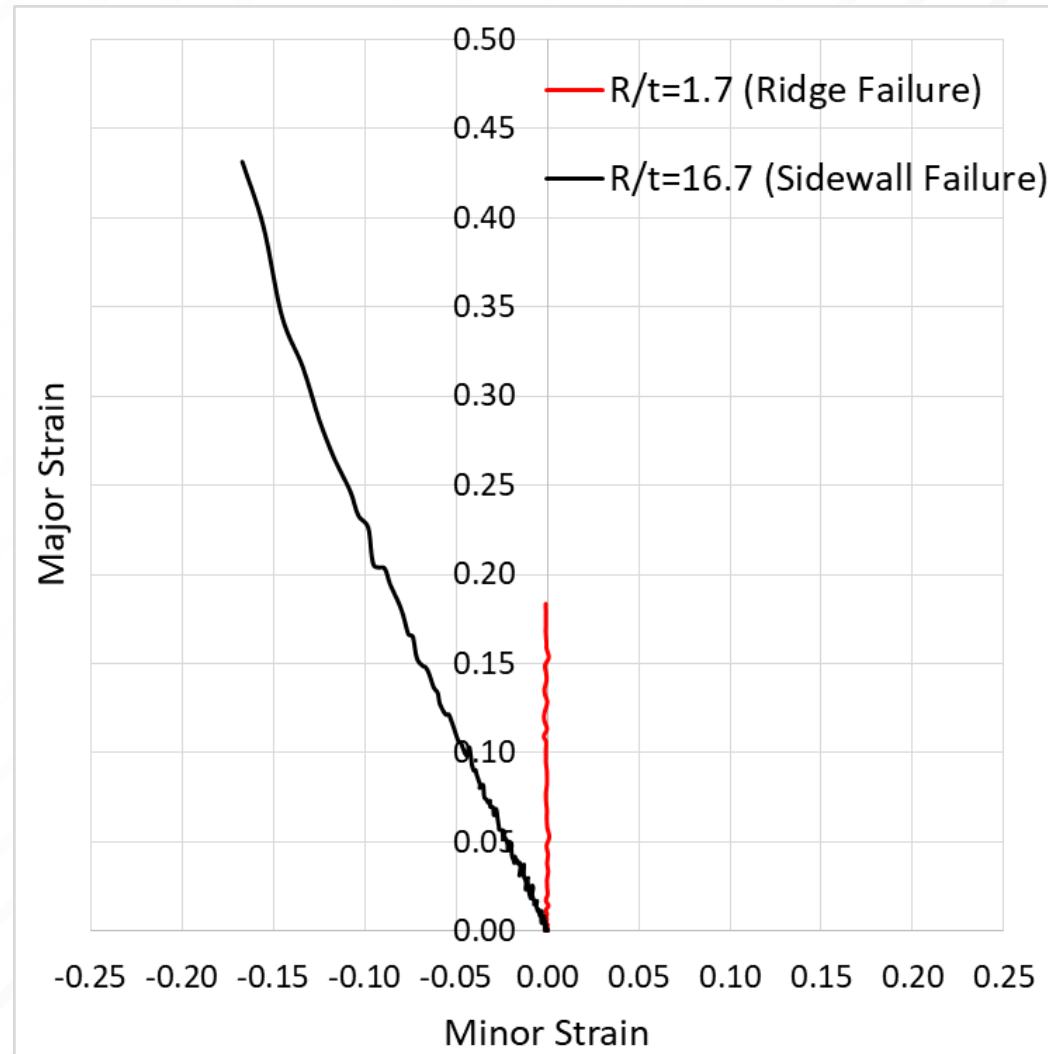
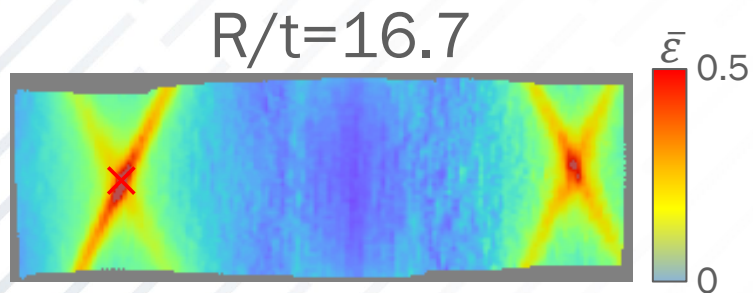
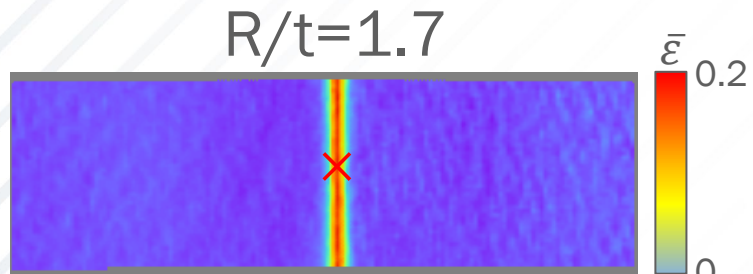
R=8.5mm R=10mm R=20mm  
(R/t=7.08) (R/t=8.33) (R/t=16.67)

# STRETCH BENDING EXPERIMENT – 3<sup>RD</sup> GEN 1180 (1.2MM)- MONOLITHIC

➤ Bendability Index (B.I.)

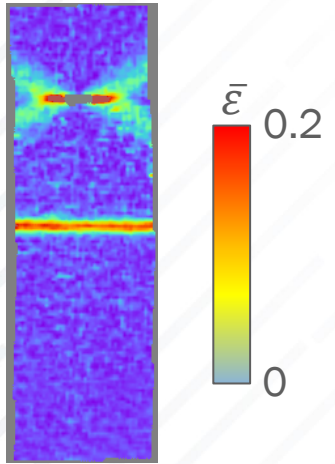


# STRAIN PATH EXAMPLE FOR MONOLITHIC BLANKS

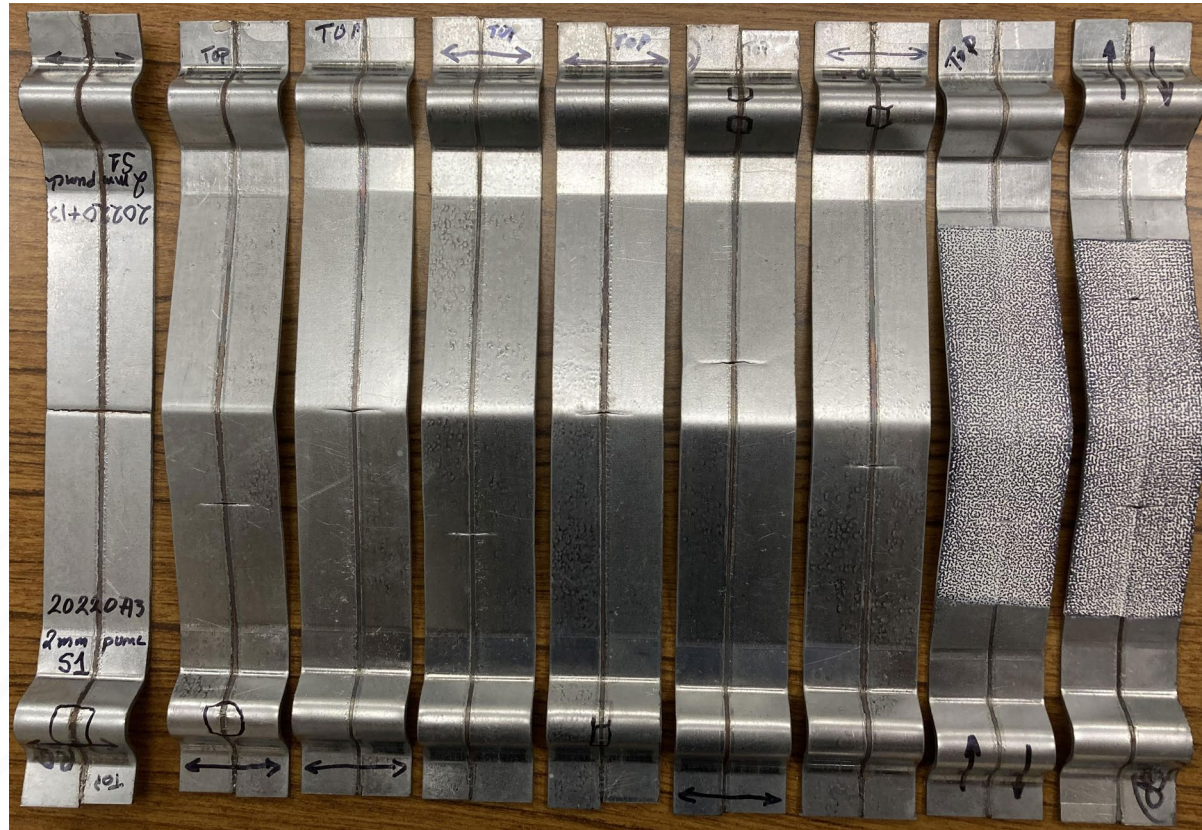
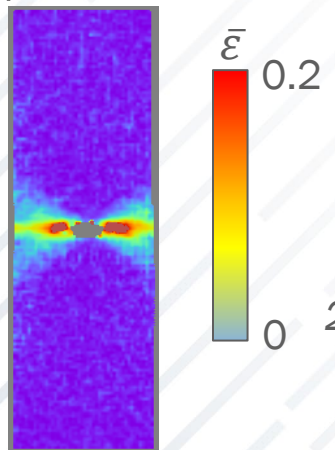


# STRETCH BENDING EXPERIMENT – 3<sup>RD</sup> GEN 1180 (1.2MM)- TWB

R/t=2.3

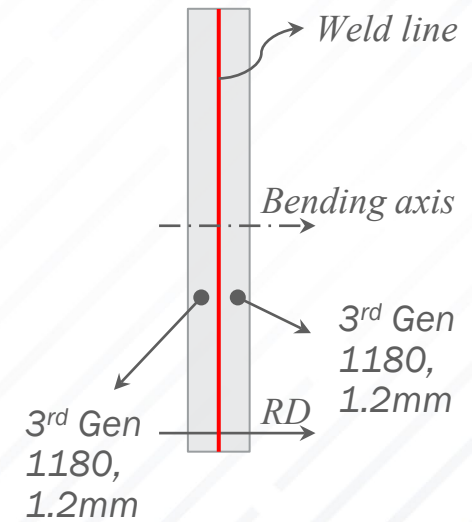


R/t=6.25

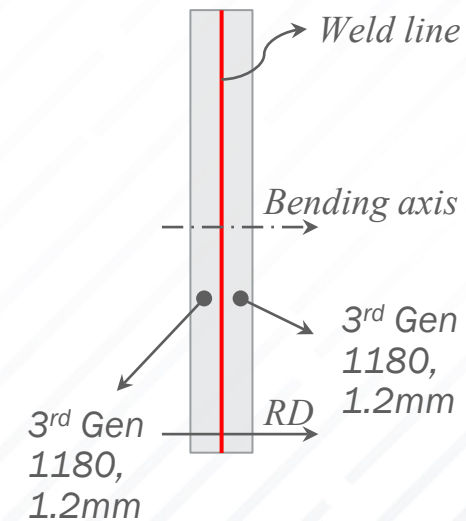
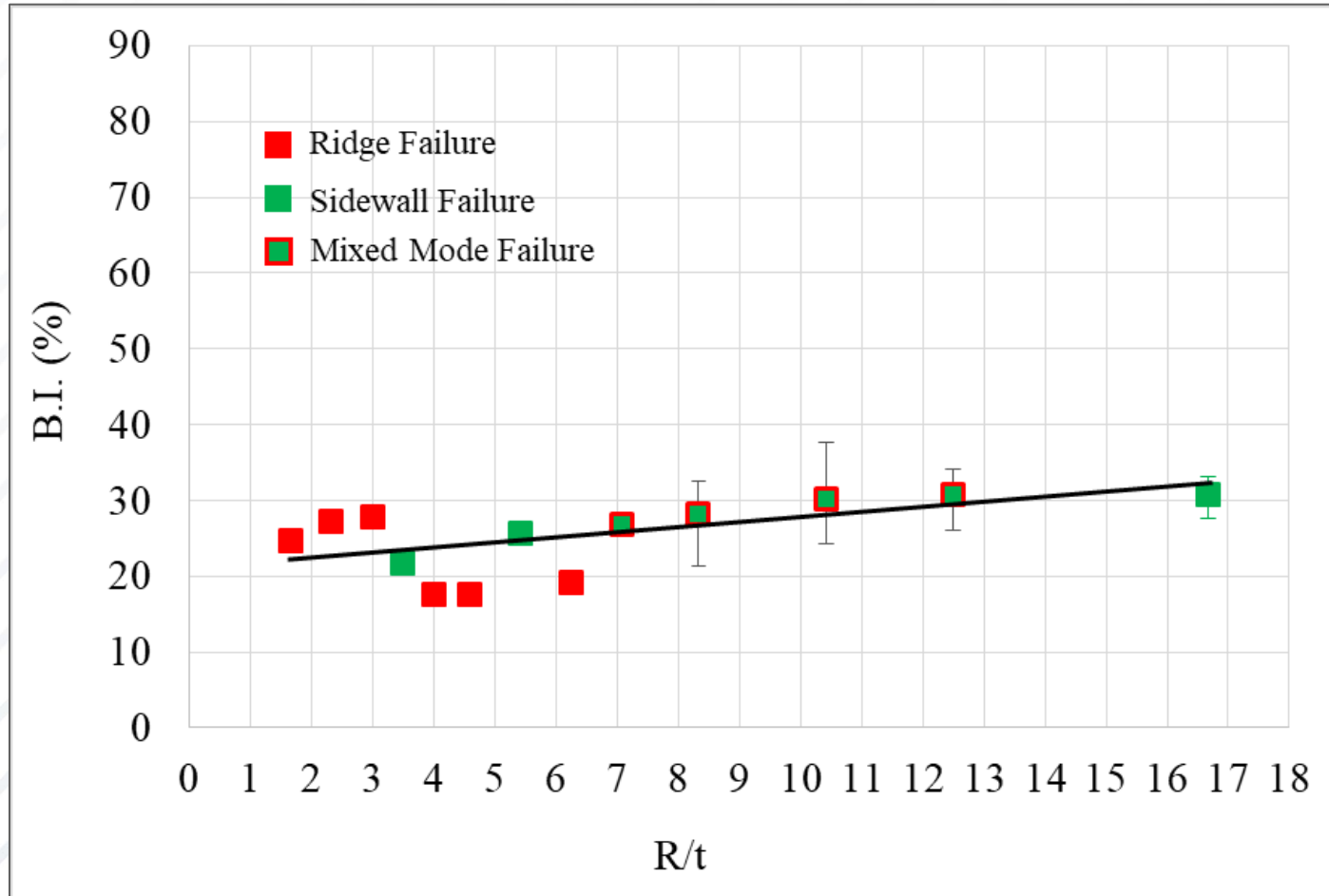


2mm punch → 20mm punch

Cracks initiated on the weld and propagated normal to the weld line into the base material

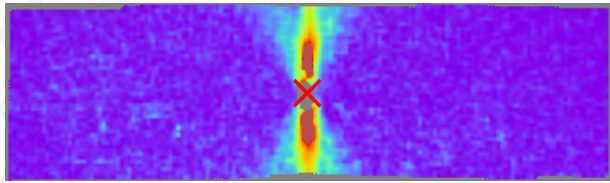


# STRETCH BENDING EXPERIMENT- 3RD GEN 1180 (1.2MM)- TWB

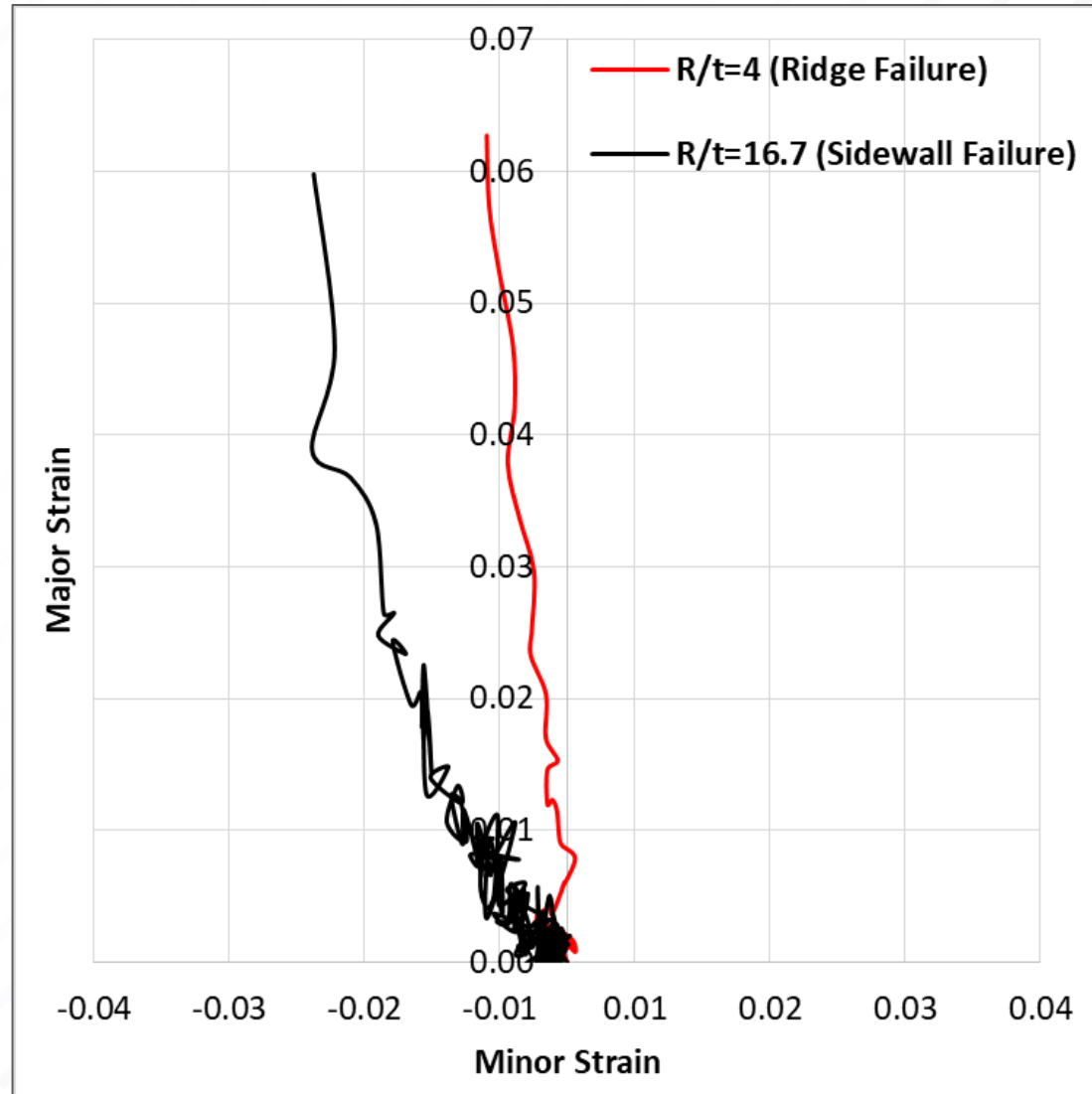
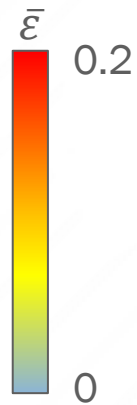
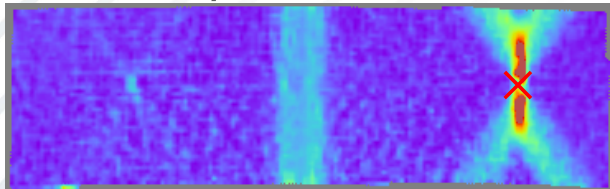


# STRAIN PATH EXAMPLE FOR TWB

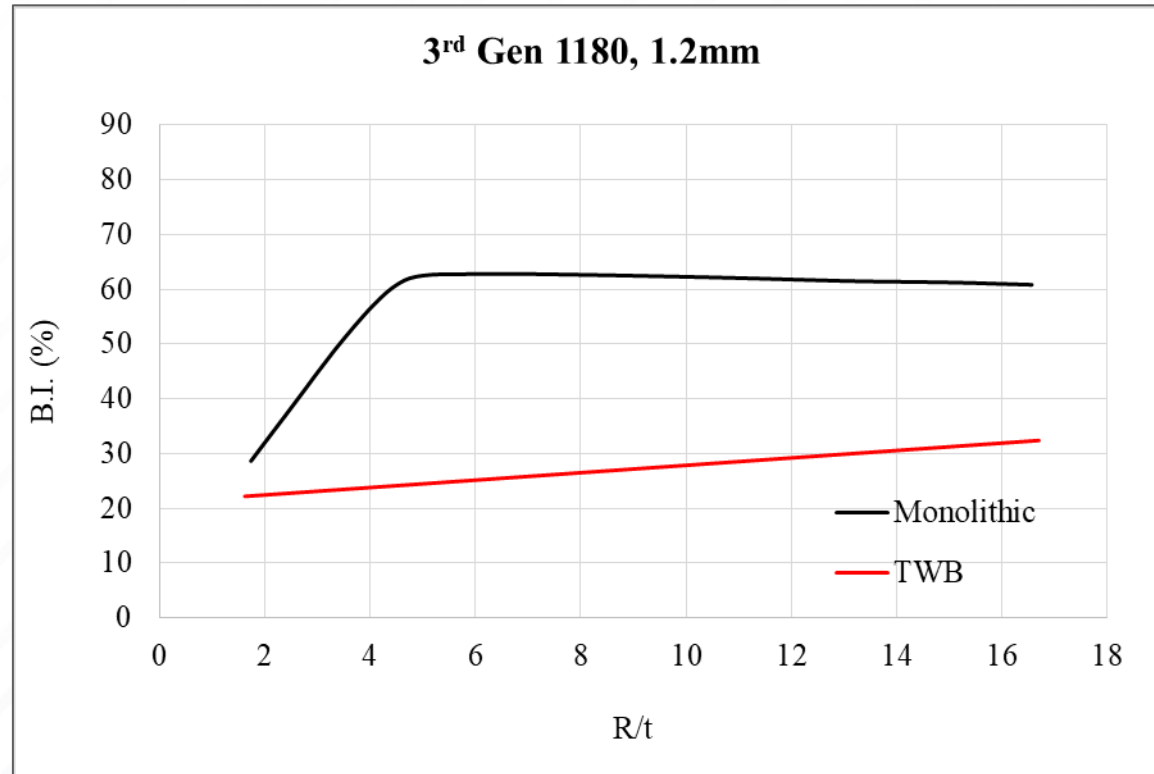
R/t=4



R/t=16.7



# STRETCH BENDABILITY- MONOLITHIC VS TWB



- Monolithic samples: B.I. significantly changes with the R/t
- TWB samples: B.I. slightly changes with the R/t

# SUMMARY & CONCLUSION

- This lab scaled die can carry out stretch bending test.
- Sample blank with 35mm width is the optimized blank.
- Bendability Index (B.I.) can be used to characterize stretch-bendability of materials.
- Bendability Index (B.I.) is significantly affected by R/t for monolithic samples.
- Bendability Index (B.I.) is slightly affected by R/t for TWB samples.

# FOR MORE INFORMATION

Name: Sobhan Nazari Tiji

Company: Cleveland-Cliffs Steel Corporation.

Email: [Sobhan.Tiji@clevelandcliffs.com](mailto:Sobhan.Tiji@clevelandcliffs.com)