

GREAT DESIGNS IN **STEEL**™

GDIS Technical Webinar Series:

Deformation Behaviour of AHSS During V-die Bending

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Deformation behaviour of AHSS during V-die Bending

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Bendability assessment methods

Parameter	Method			
	ASTM E290-14	ISO 7438-2005	VDA 238-100	V-die bending
Punch radius	-	-	-	1, 2, 3 mm
Supports radius	-	-	-	4 mm
Sheet width	$w \geq 18 \text{ mm}$	$w = 20 \pm 5 \text{ mm}$	$w \geq 20t \text{ mm}$	25 mm*
Bending span	$L = (2R_p + 3t) \pm t/2$ $6 \leq L \leq 8.6 \text{ mm}$	$L = (2R_p + 3t) \pm t/2$ $6 \leq L \leq 8.6 \text{ mm}$	$L = 2t + 0.5$ $L = 3.7 \text{ mm}$	50 mm
Max load	-	-	-	30 kgf*
Testing criterion	Angle before first crack (unloaded)	Angle before first crack (loaded)	Angle at max load	Min radius without crack



3-point bending

*Adjusted dimensions to fit McMaster's die.

Objectives

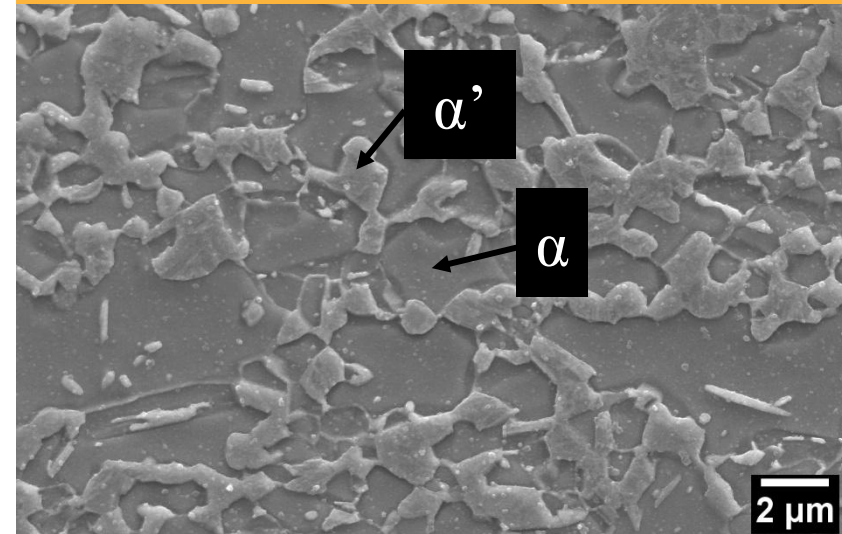
Effect of the microstructure on the bendability of AHSS for automotive applications

- Looking through the perspective of three AHSS with the same nominal strength (DP980, QP980 and CP980):
 - Assess the differences in testing setup: three-point versus V-die bending;
 - Evaluate the effect of the microstructure on strain distribution and evolution at the bending spine and springback.

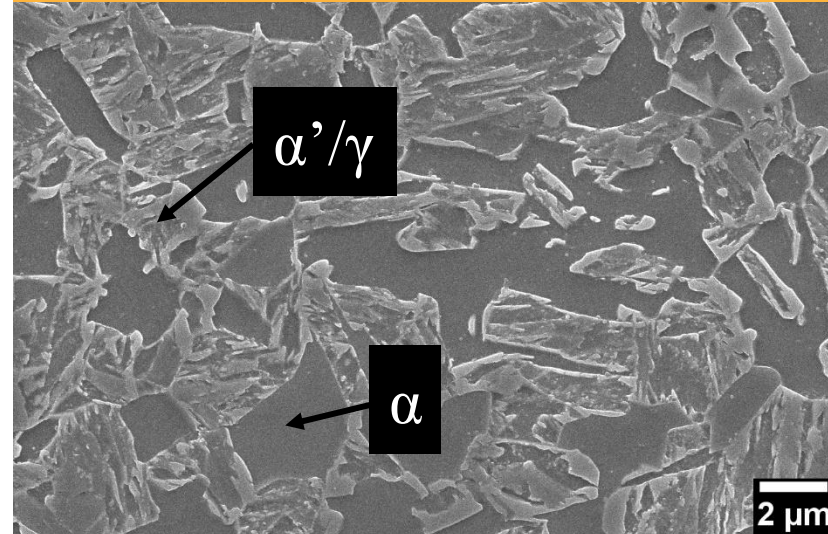
Materials

➤ Cold-rolled, 1.6 mm thick sheets

DP980

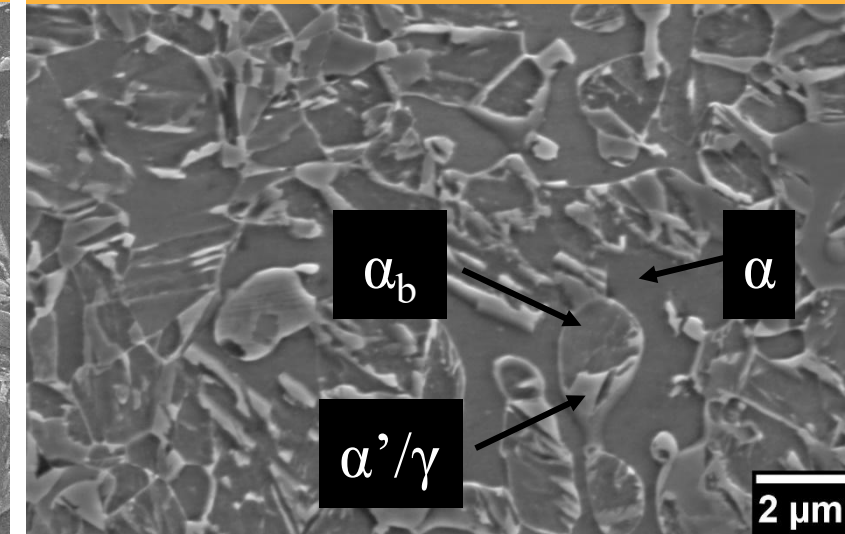


QP980



$\gamma \sim 6\%$

CP980

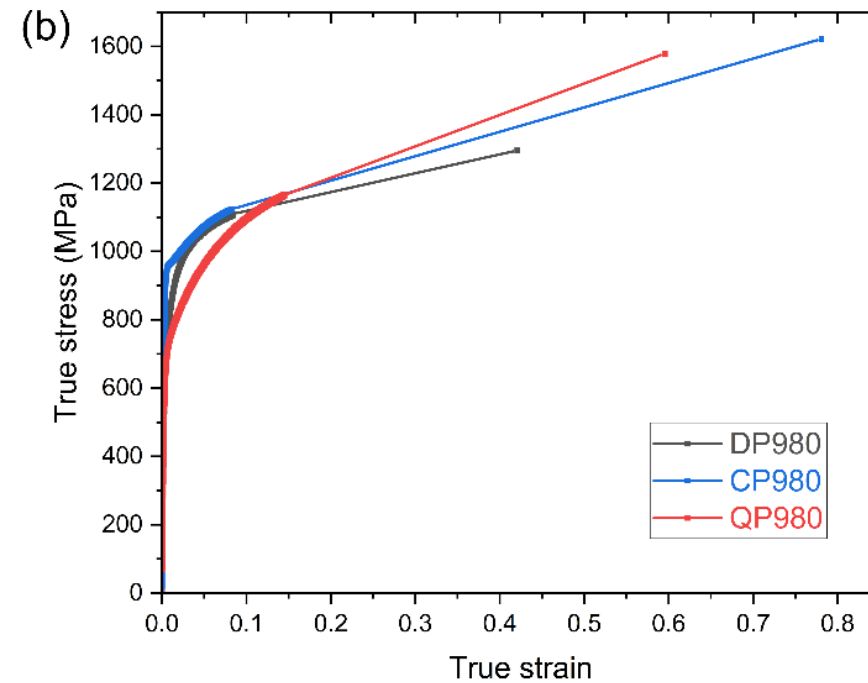
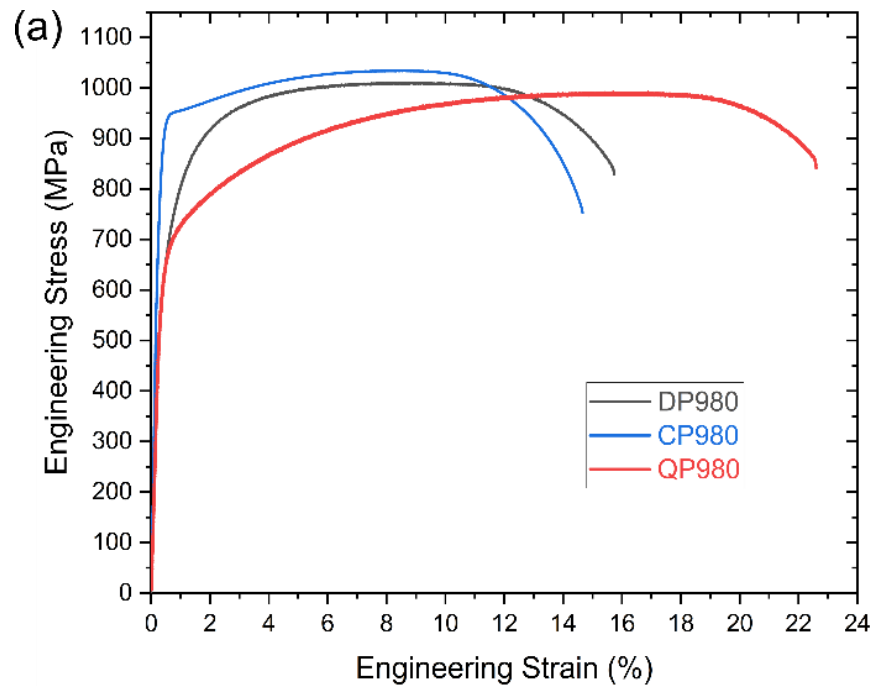


$\gamma \sim 6\%$

α : ferrite
 α' : martensite

γ : austenite
 α_b : bainite

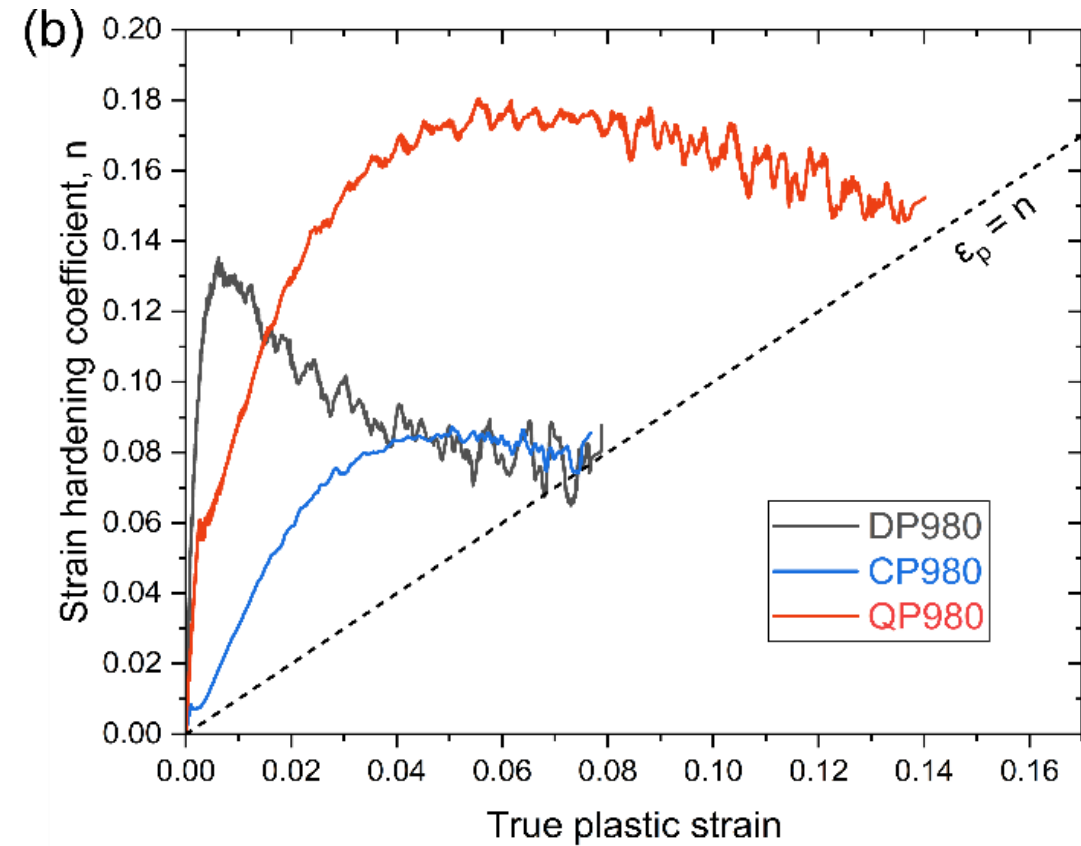
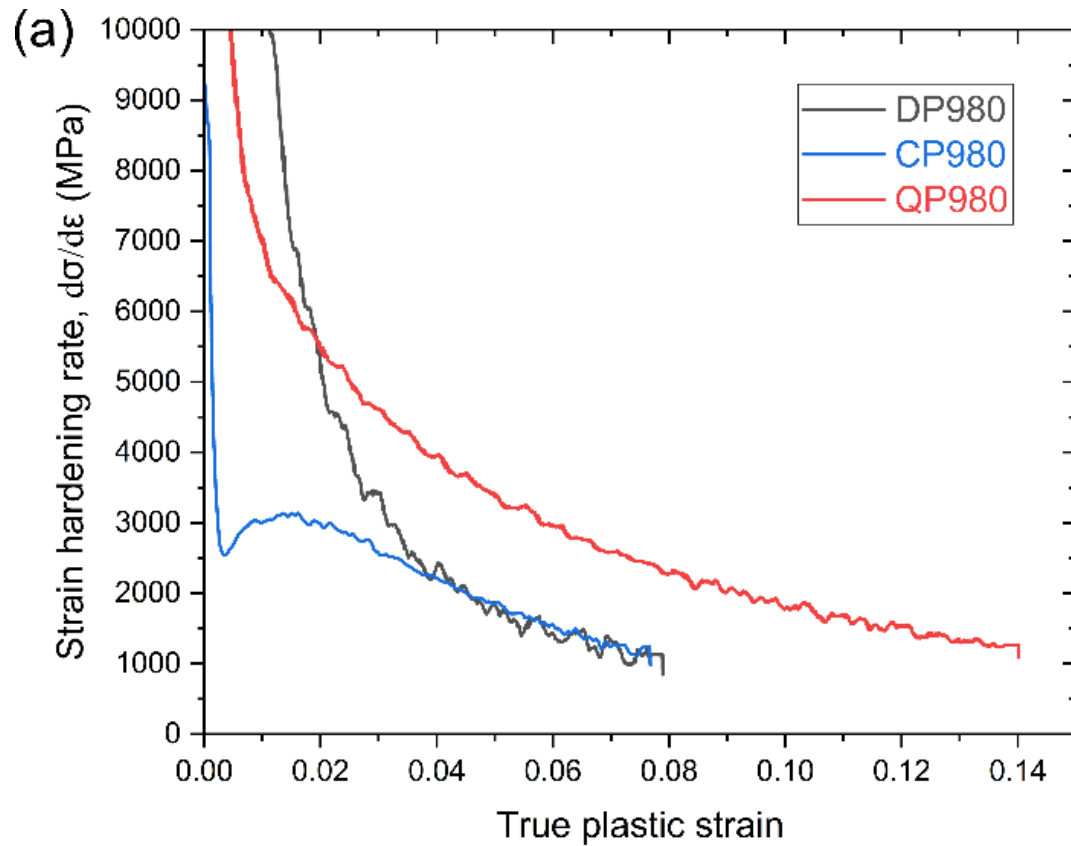
Tensile Properties



	YS (MPa)	UTS (MPa)	Uniform Elong. (%)	Total Elong. (%)
DP980	662	1016	8.9	15.8
QP980	654	1005	15.9	22.1
CP980	941	1046	8.2	14.6

*Properties representative of samples provided only.

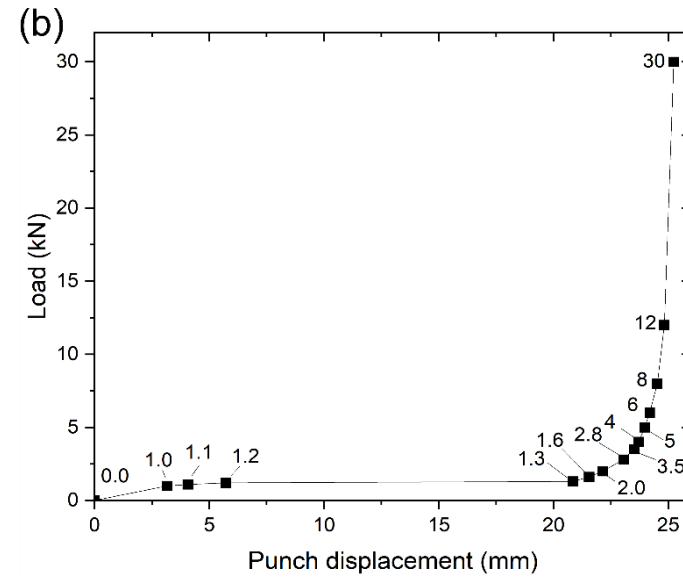
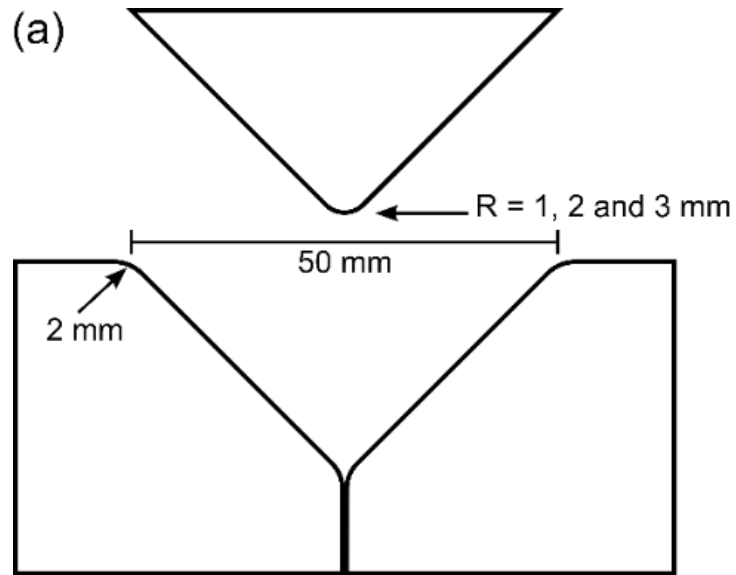
Strain hardening



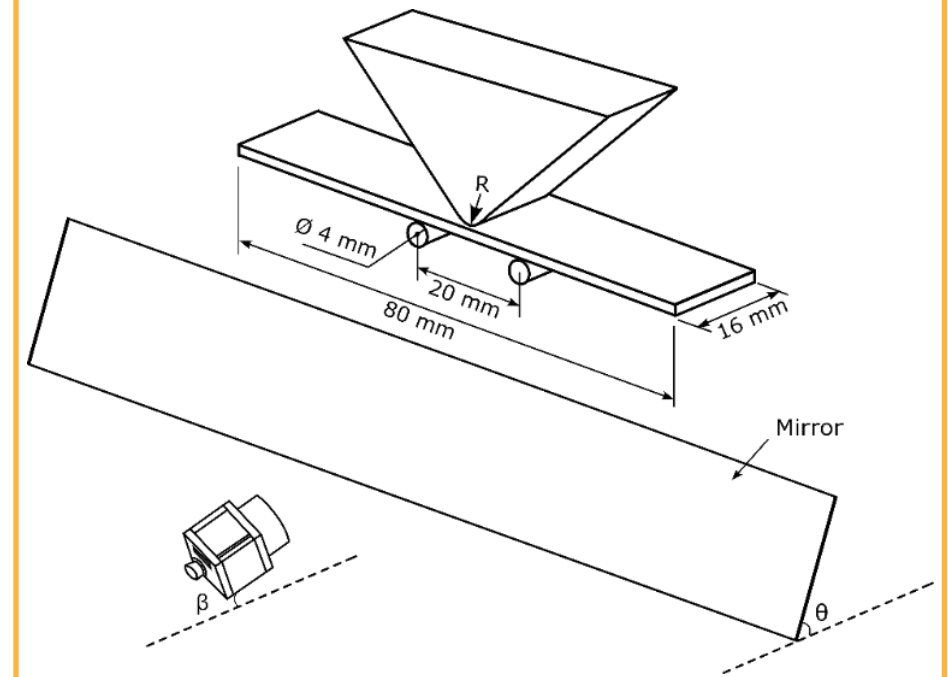
$$\text{Strain hardening rate} = \frac{d\sigma}{d\varepsilon}$$

$$n = \frac{d \ln \sigma}{d \ln \varepsilon}$$

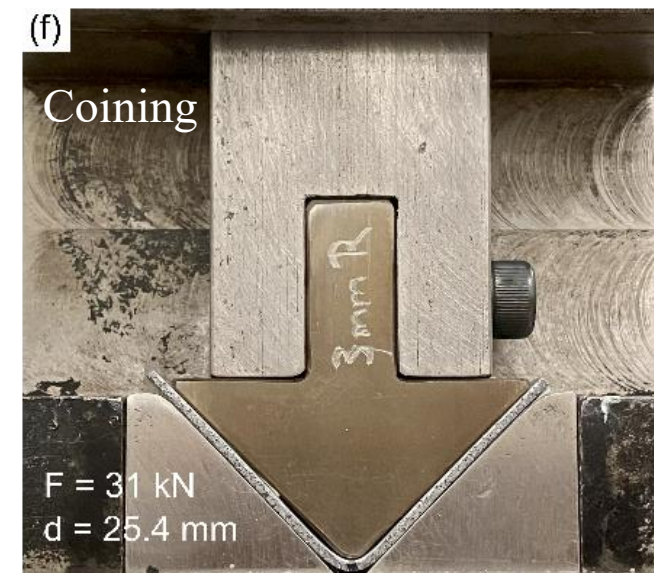
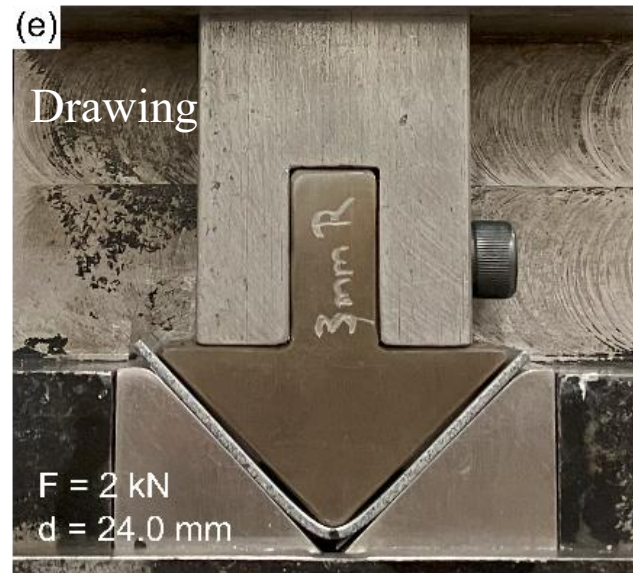
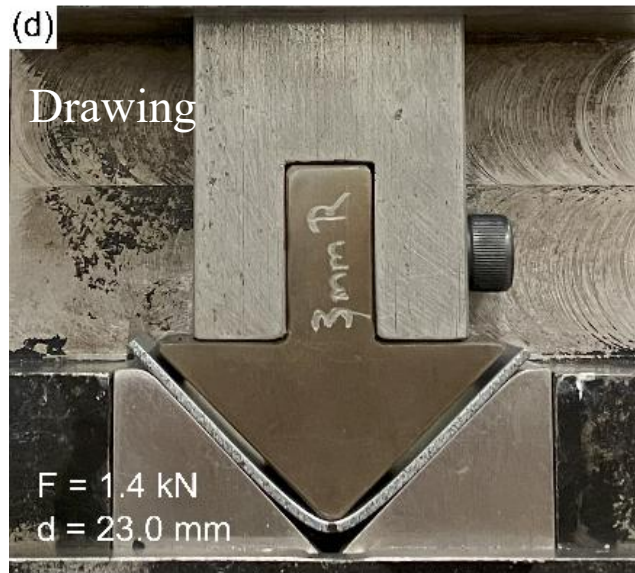
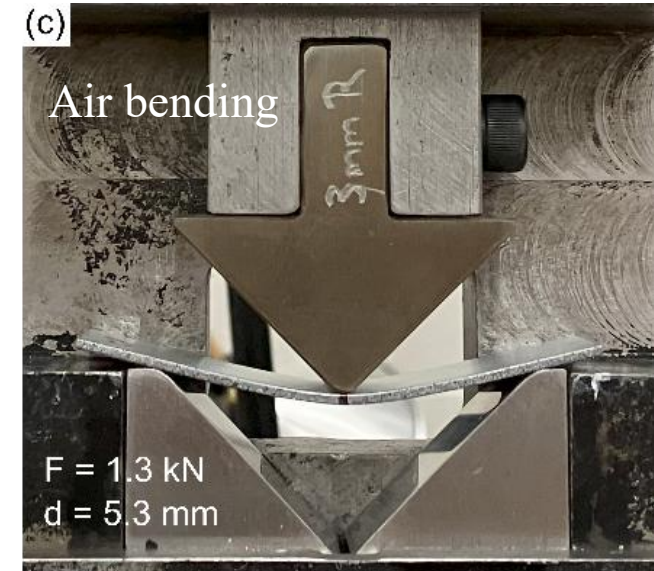
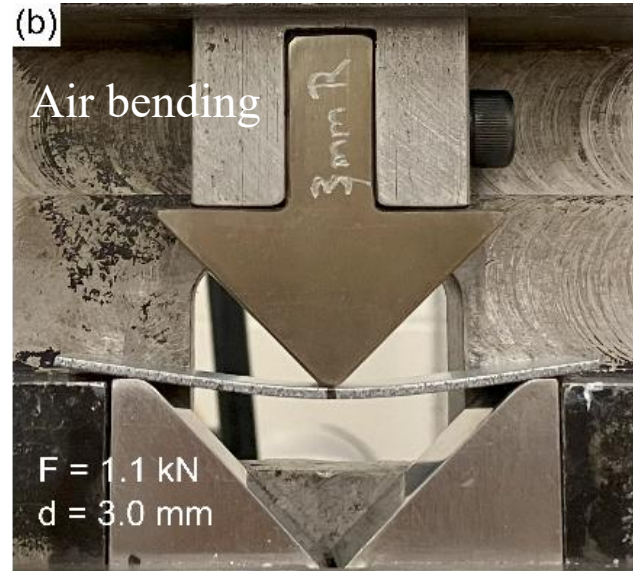
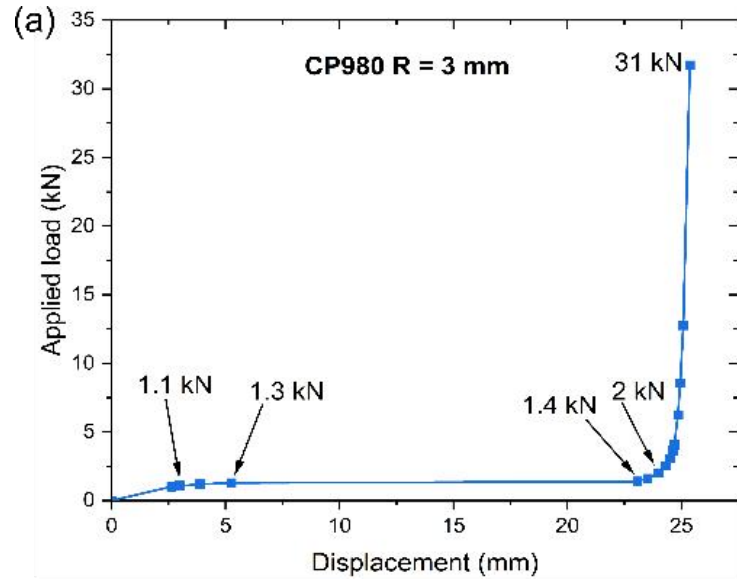
Interrupted V-die tests + 3D DIC



3-point bend tests + 2D DIC

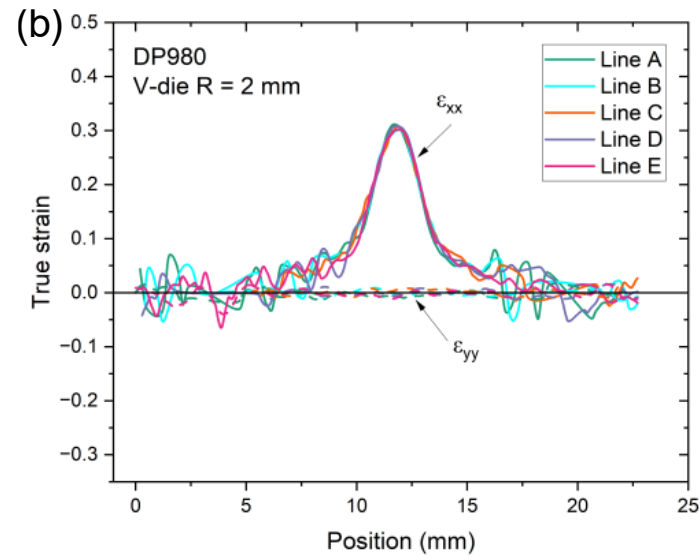
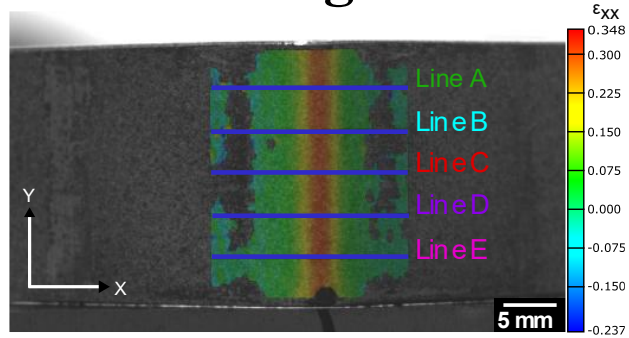


Stages of V-die bending

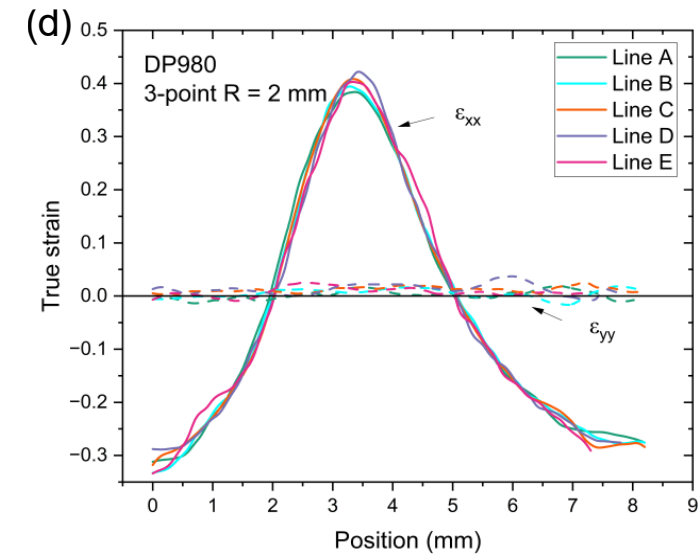
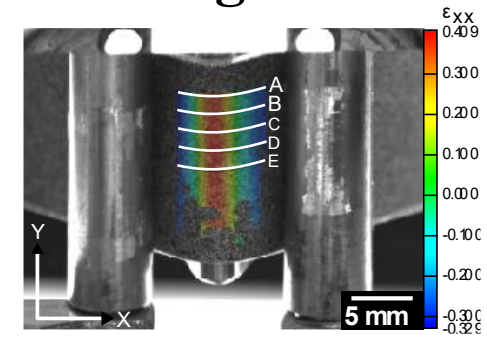


V-die vs. 3-point bending: DP steel

V-die bending R = 2 mm



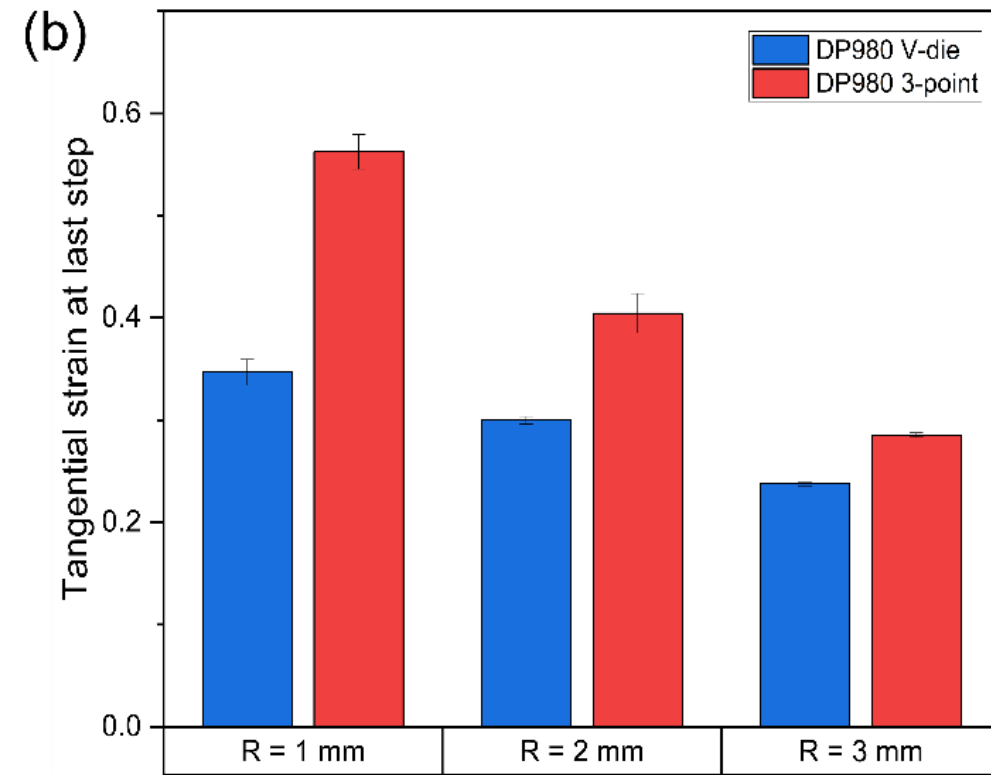
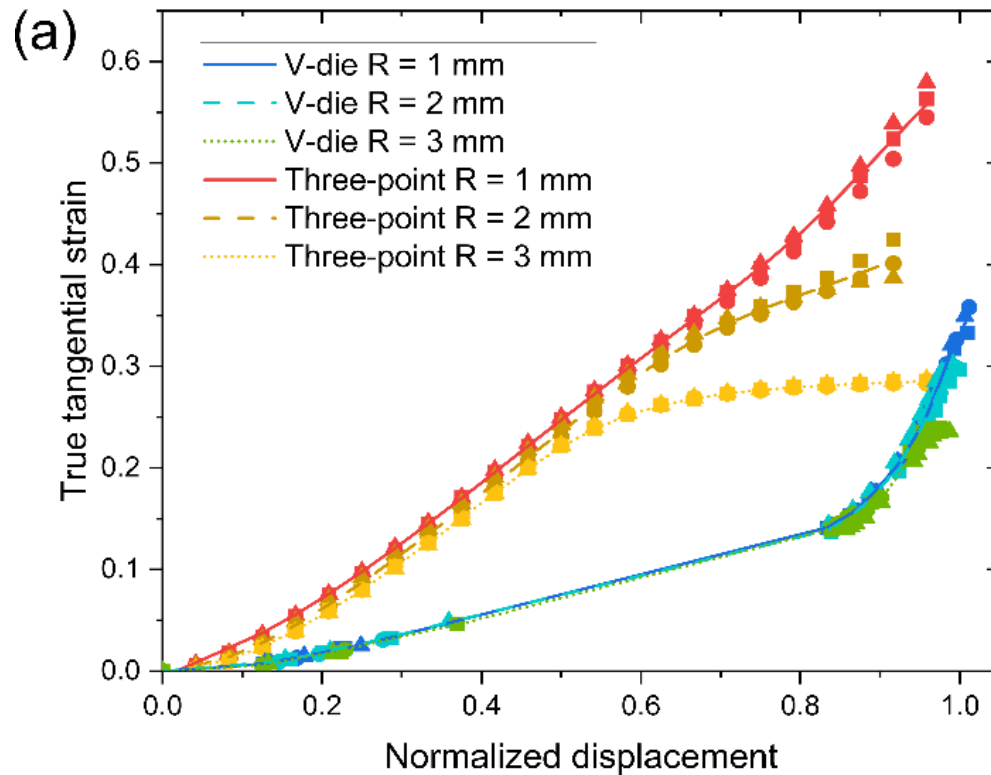
3-point bending R = 2 mm



Strain concentrated at bending spine, plane strain condition.

V-die vs. 3-point bending: DP steel

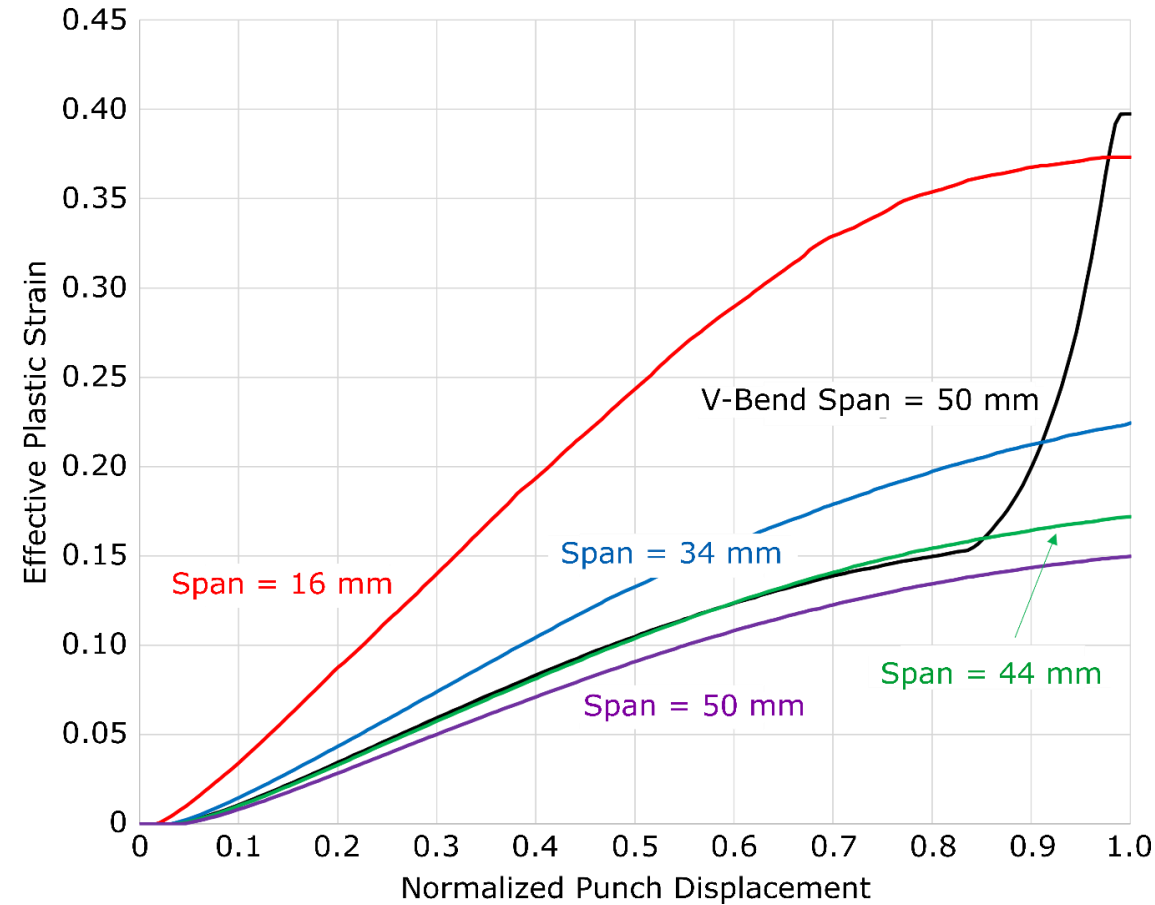
➤ Peak tangential strain



Tighter radius, higher strain.
Tangential strain increases faster for 3-point bending.

V-die vs. 3-point bending: DP steel

➤ FE simulations



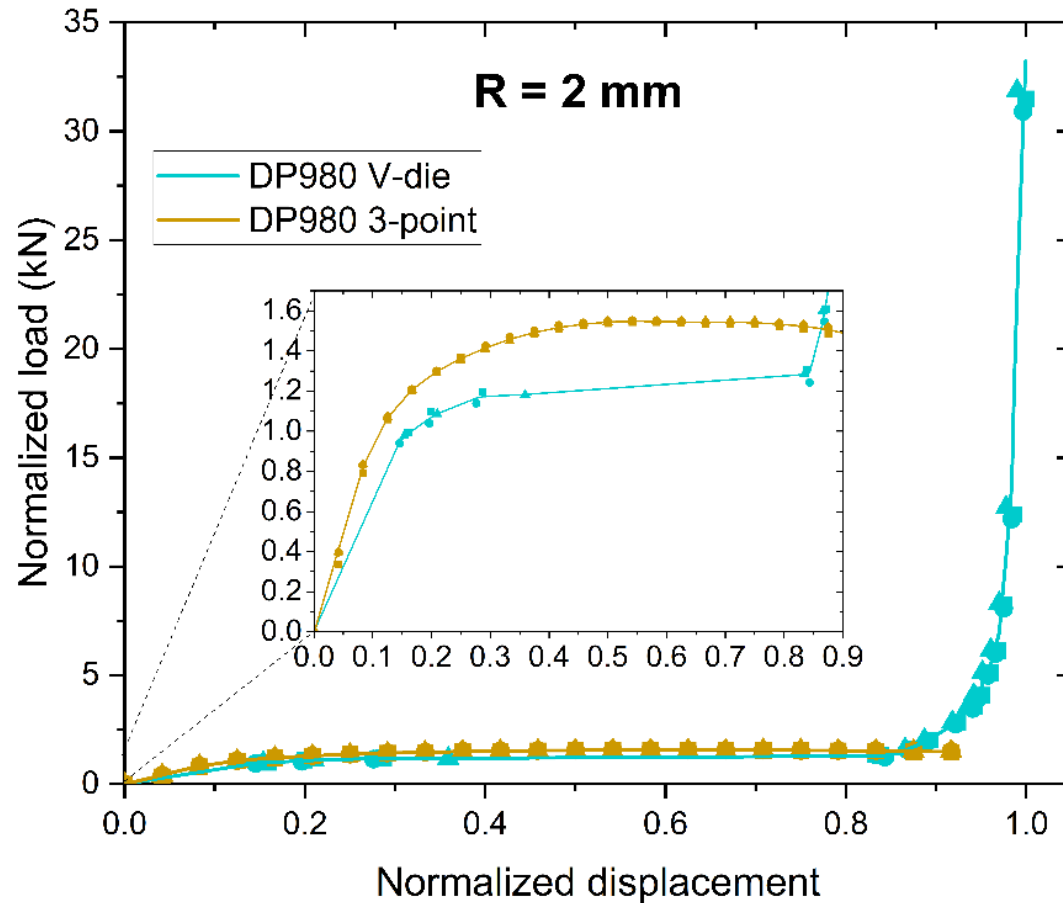
Shorter bending span, higher strain levels.

V-die vs. 3-point bending: DP steel

➤ Load during air-bending stage

- Normalized load: account for width and moment arm differences.

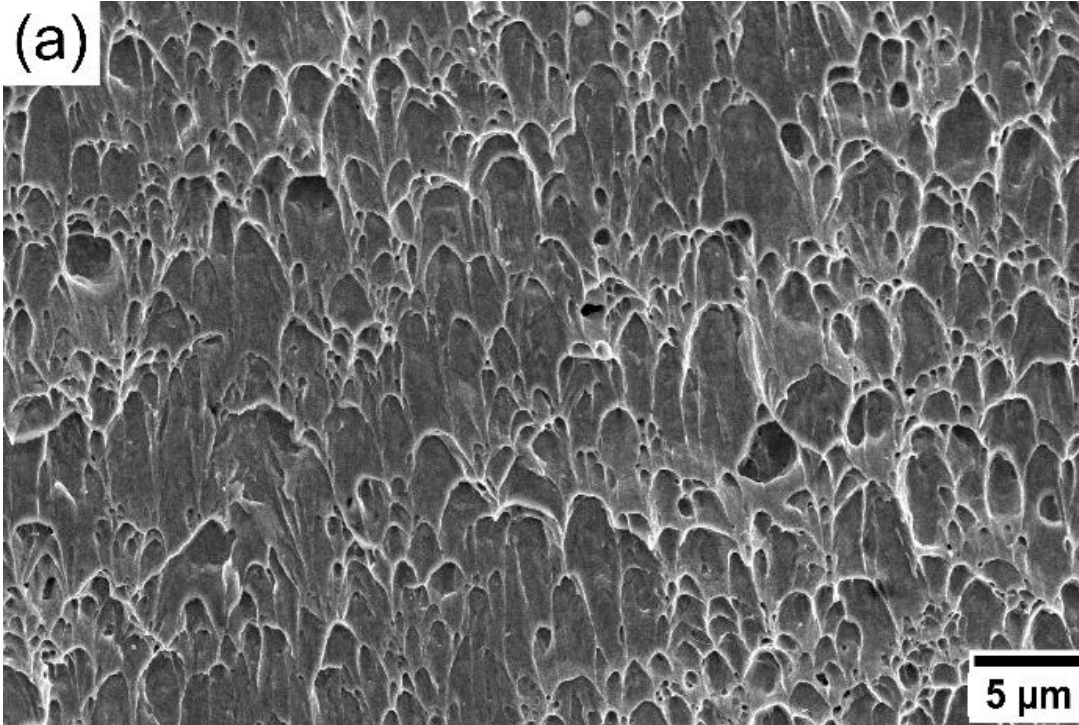
$$\bar{F} = \frac{F}{w} \frac{L_0}{2}$$



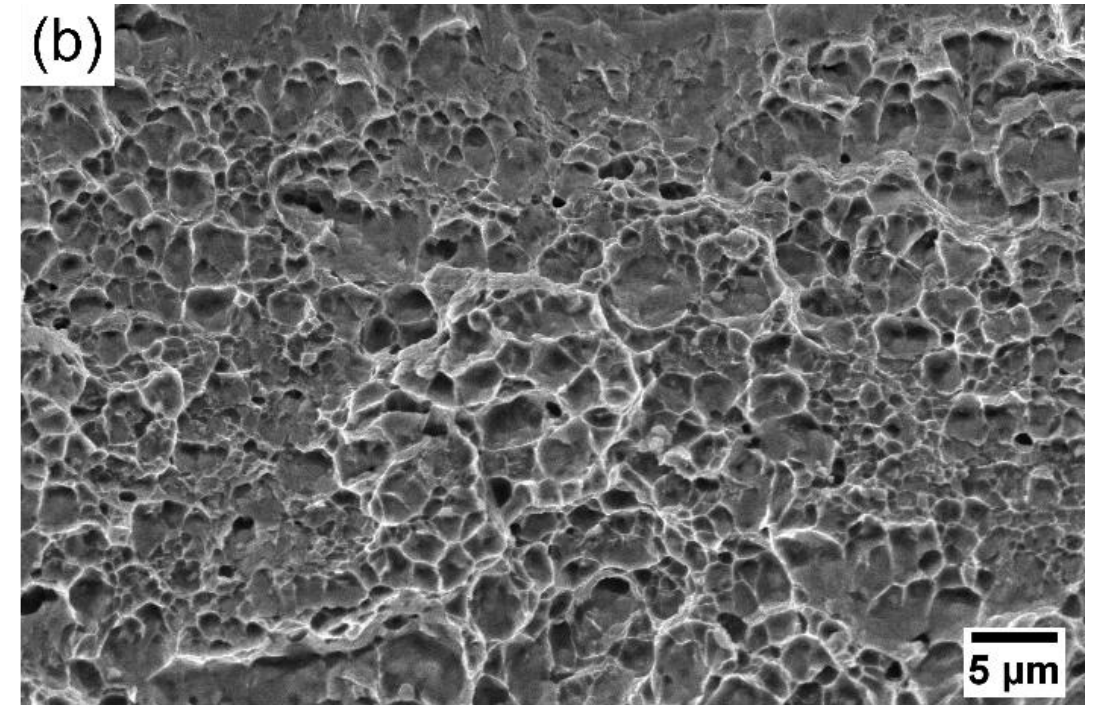
Air bending stage of V-die test ~ 3-point bending

V-die vs. 3-point bending: DP steel

V-die bending $R = 1$ mm

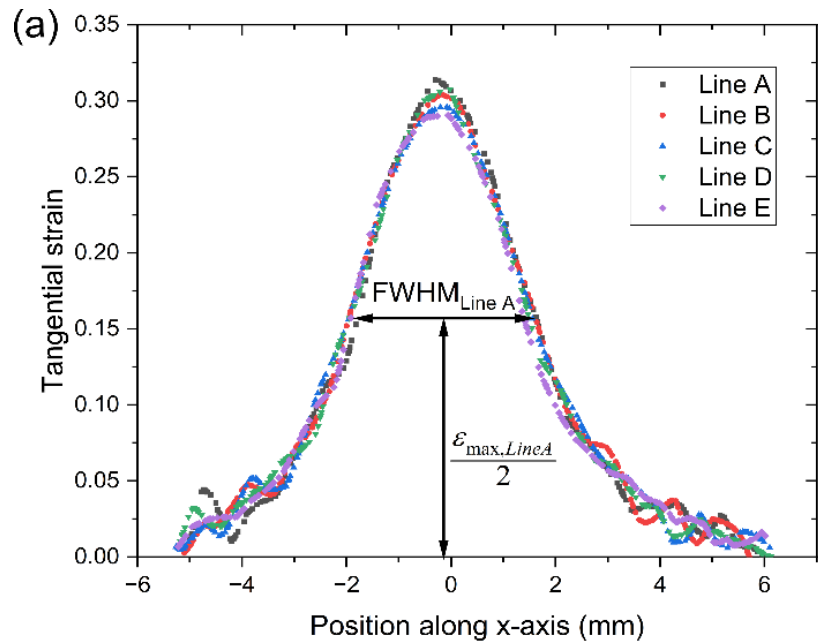
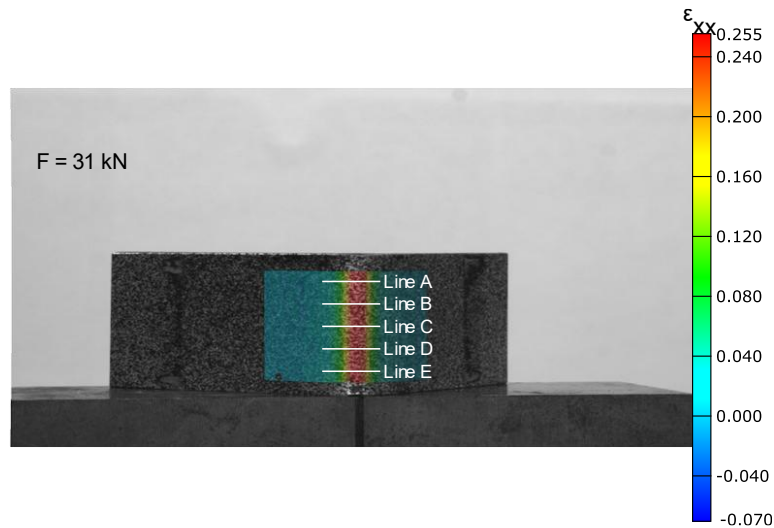


3-point bending $R = 1$ mm

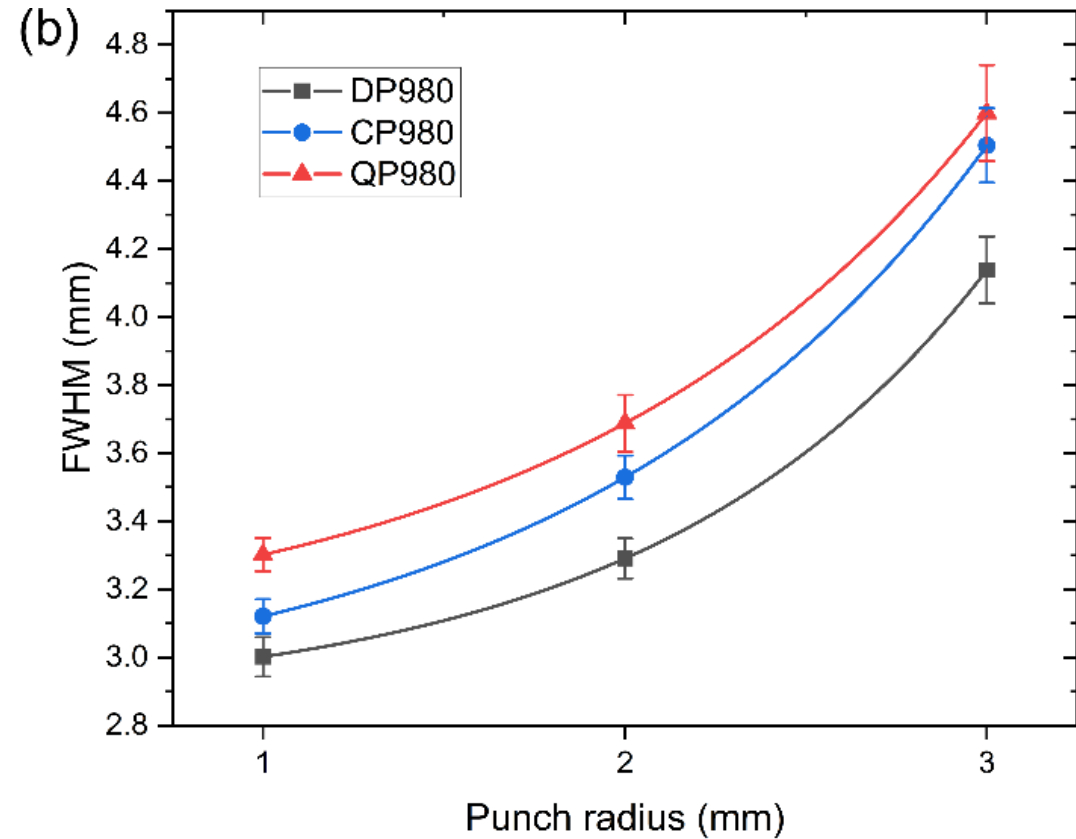


Dimples are shallower for V-die sample.

V-die bending: strain distribution

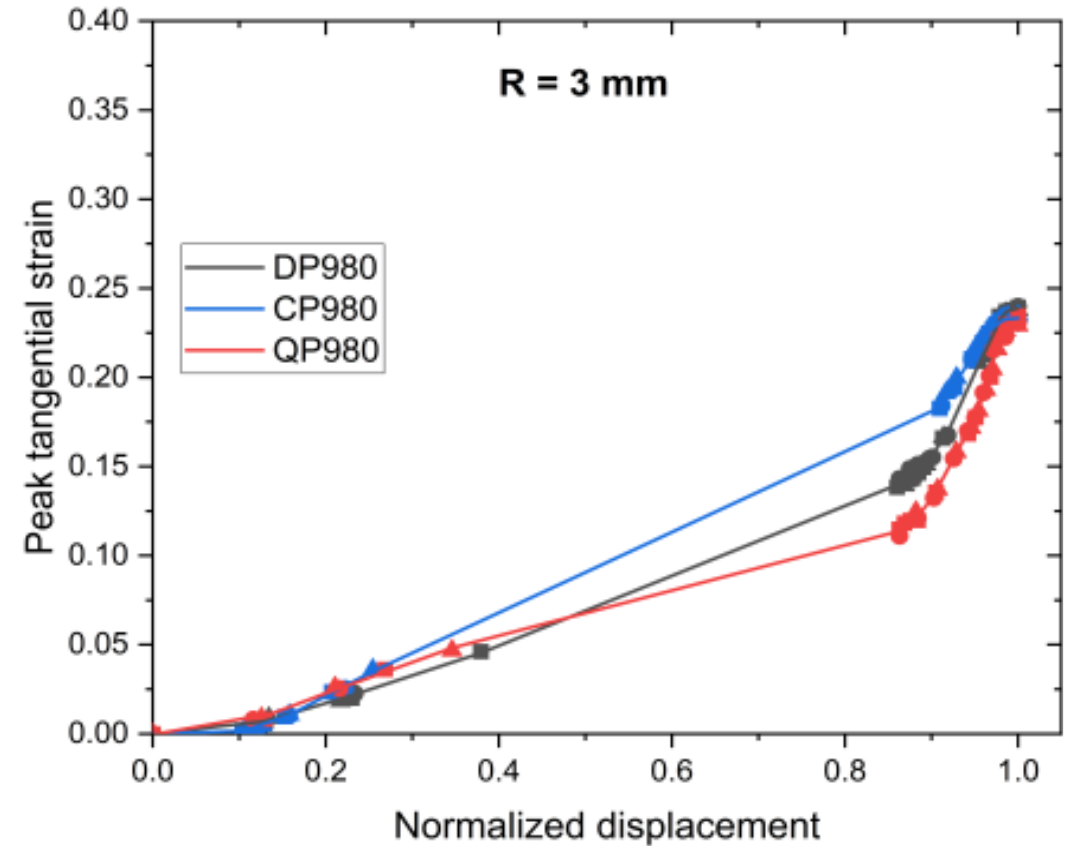
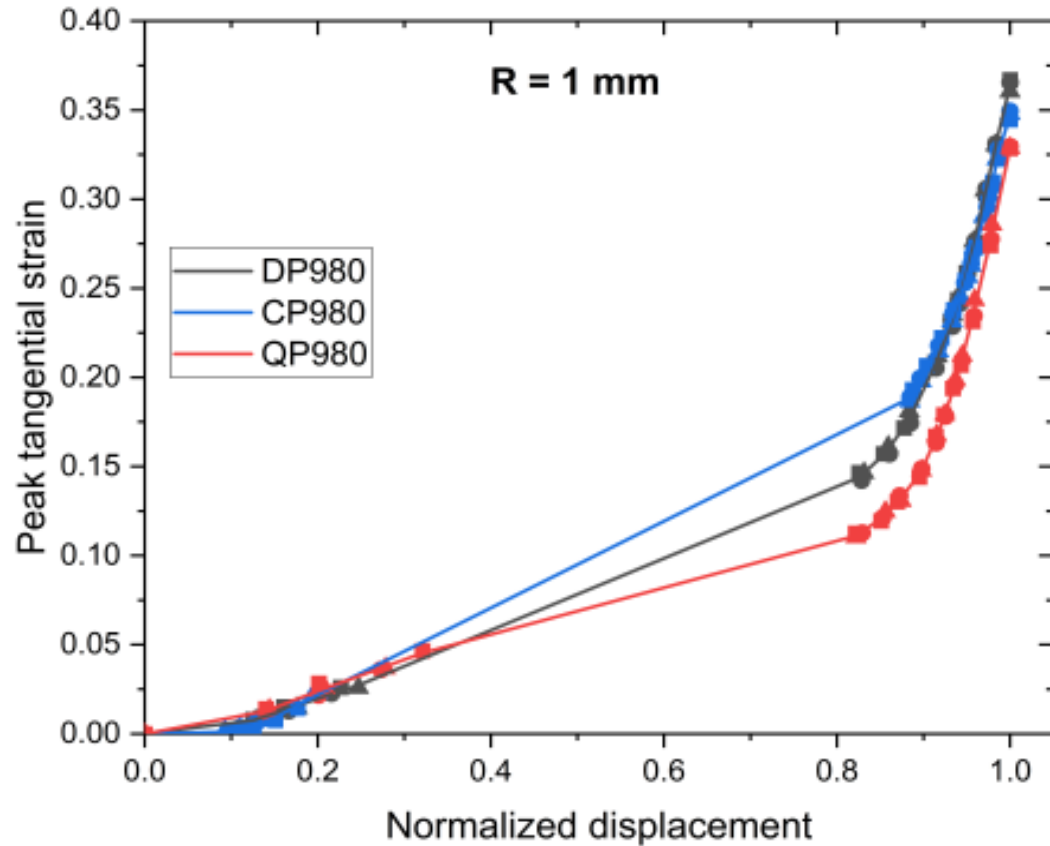


FWHM: Full Width at Maximum Height



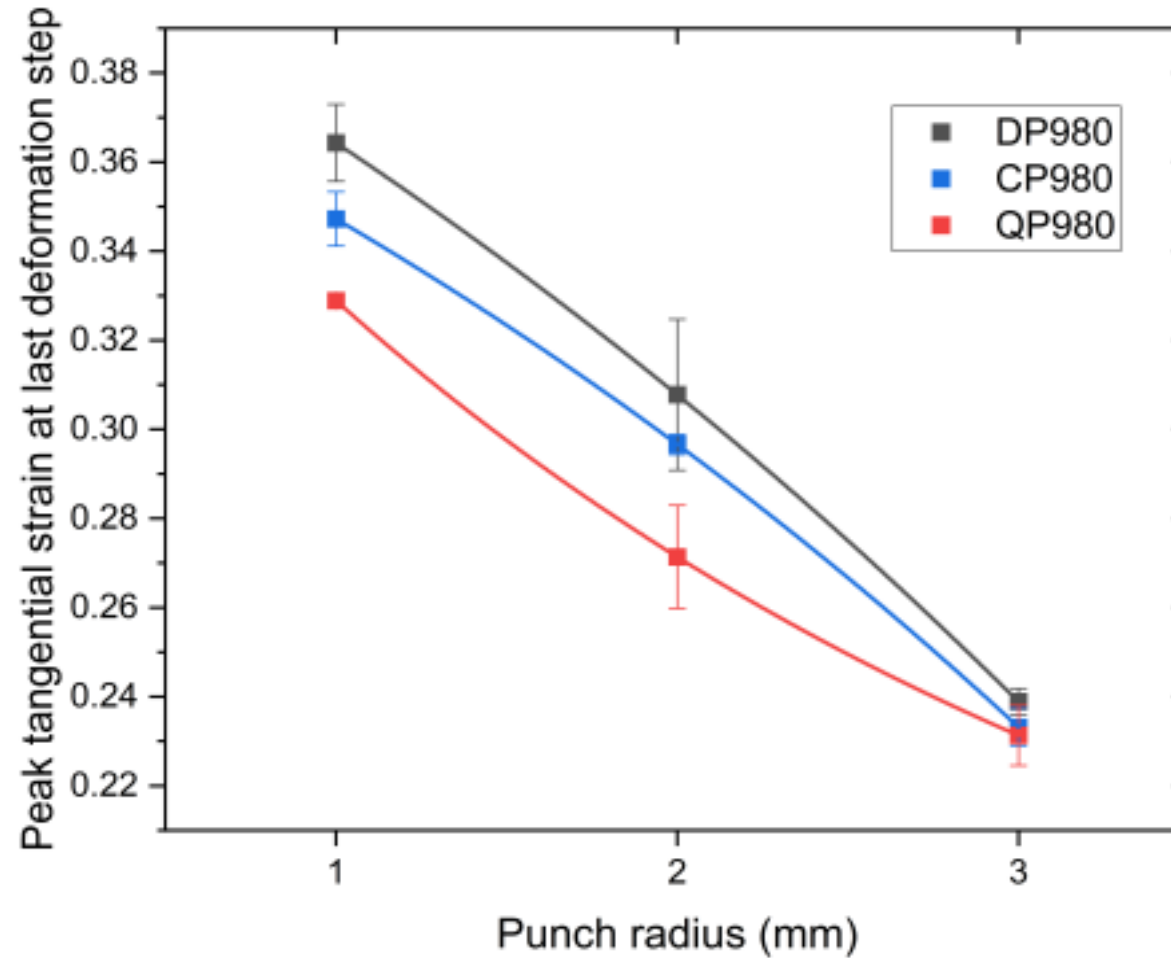
Strain concentration severity: DP > CP > QP

V-die bending: peak strain evolution



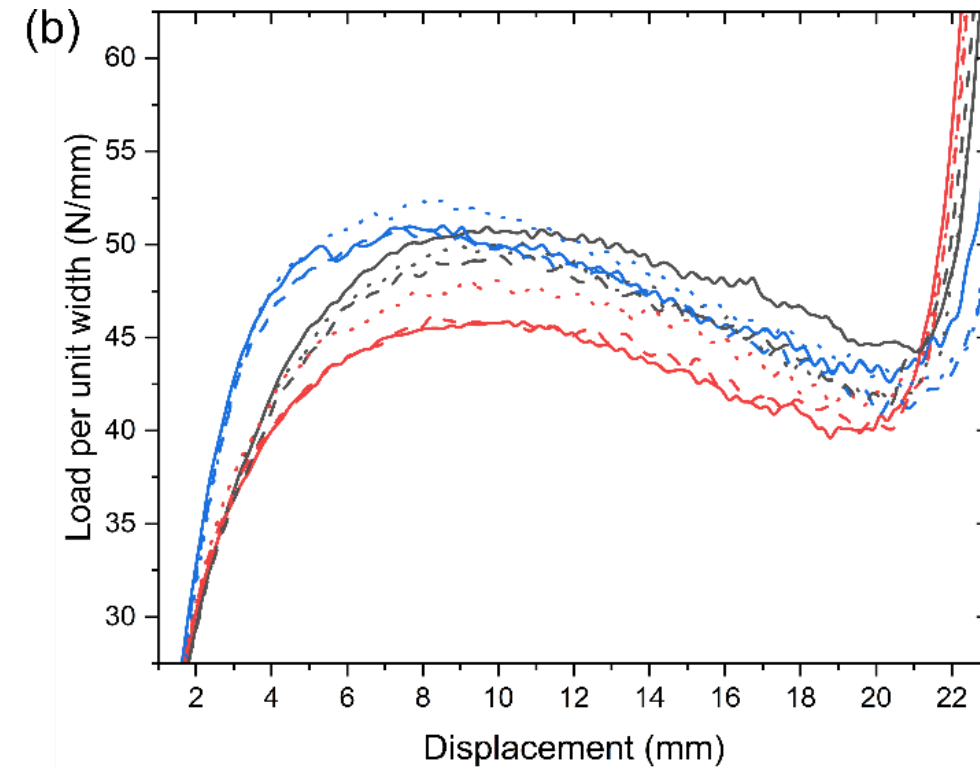
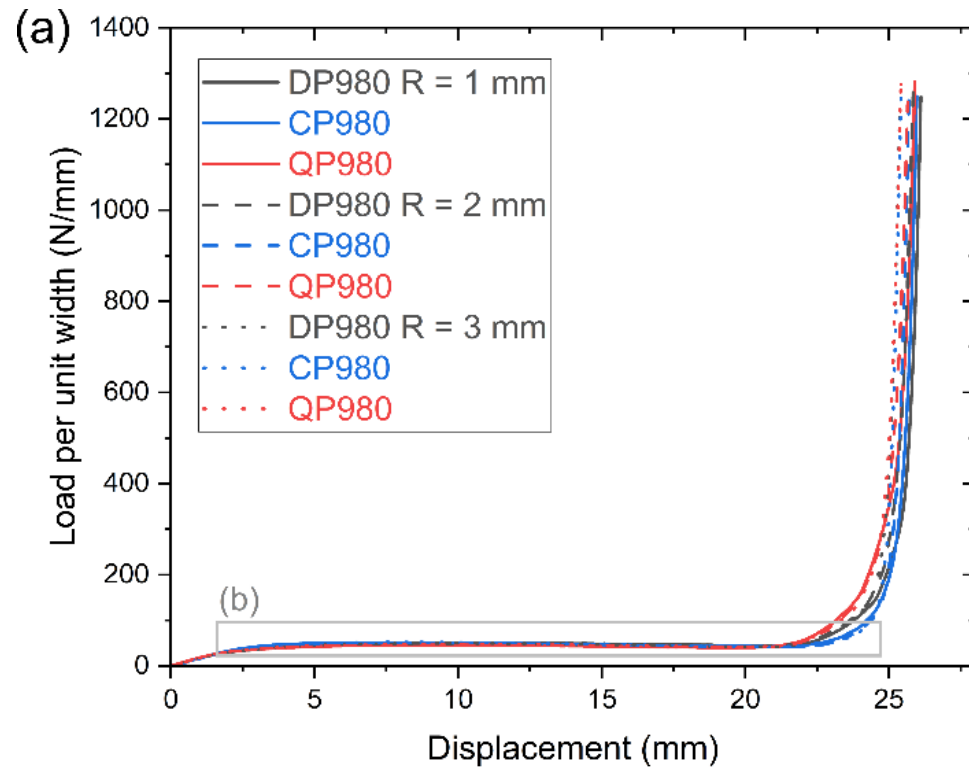
Strain at bending spine: DP > CP > QP

V-die bending: peak strain at end of tests



Strain at bending spine: DP > CP > QP

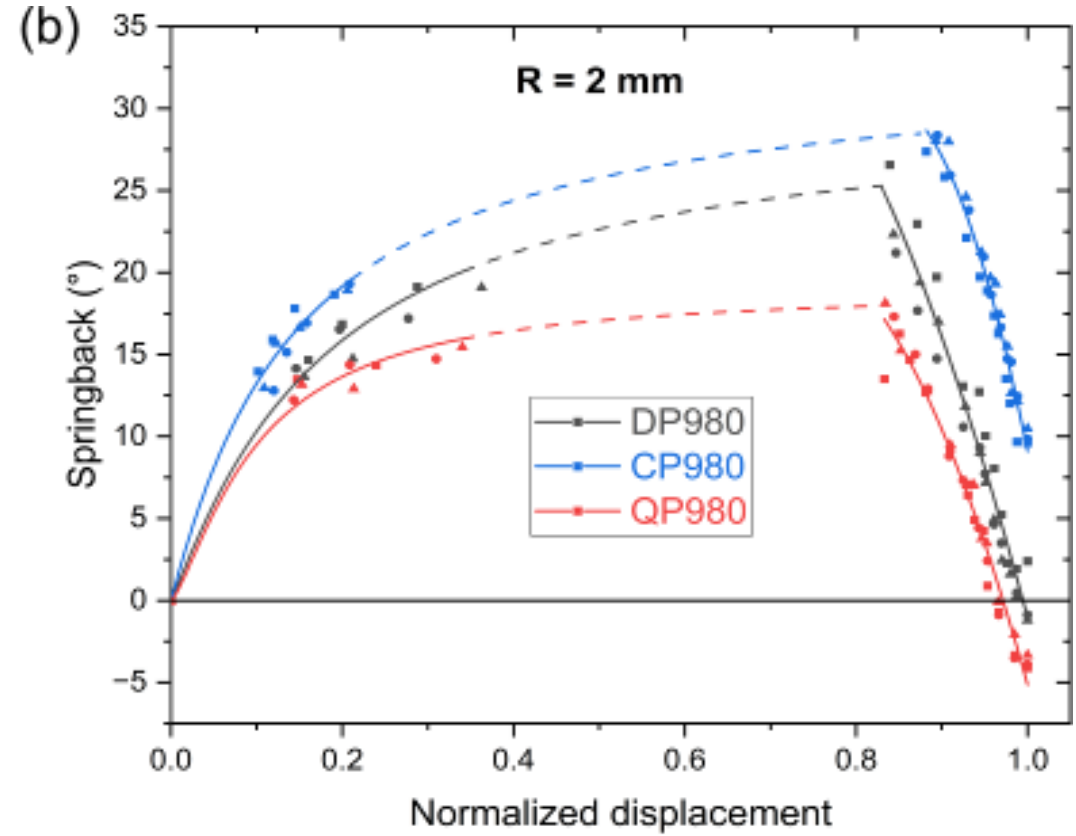
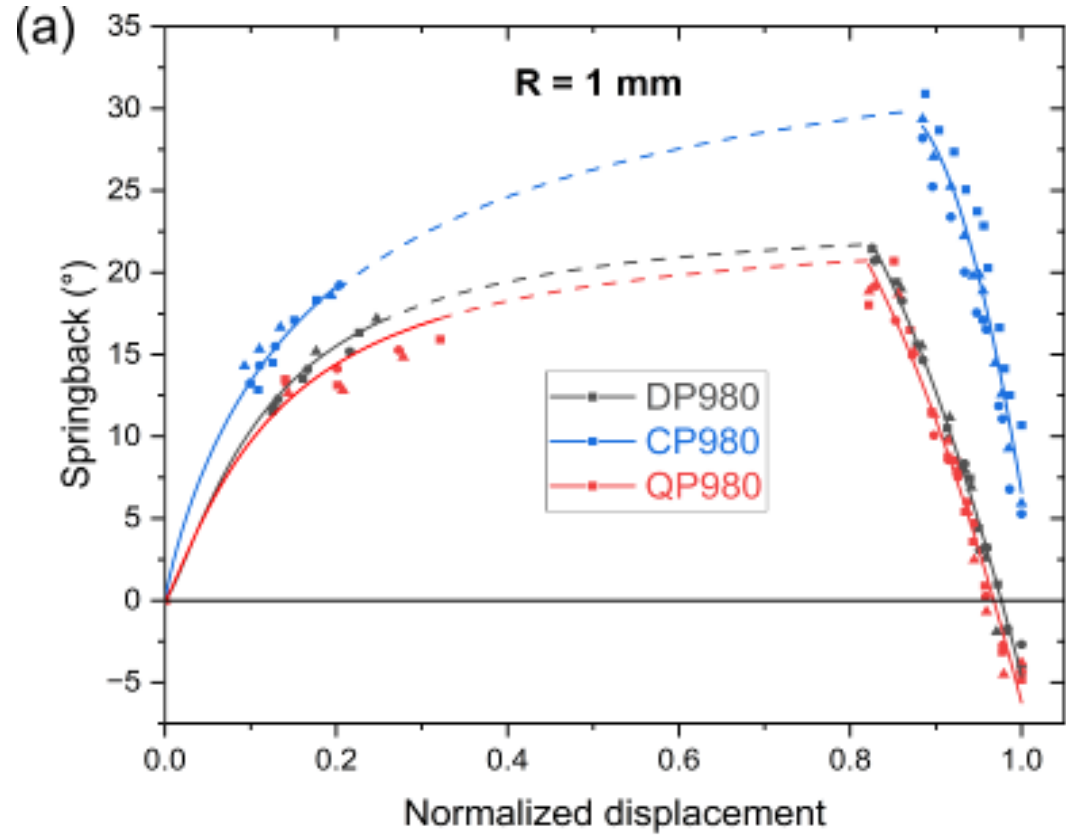
V-die bending: load evolution



Applied load: CP > DP > QP

V-die bending: springback angle

$$\Delta\alpha = \alpha_{loaded} - \alpha_{unloaded}$$

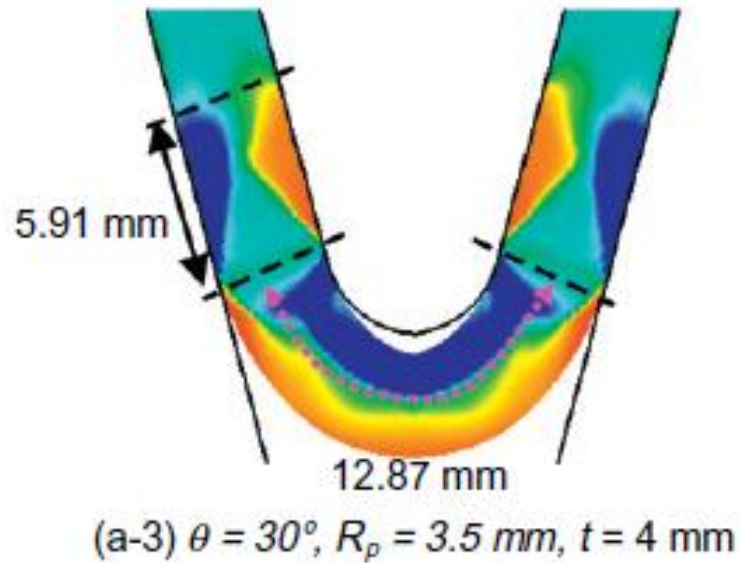


Springback angle: CP > DP > QP

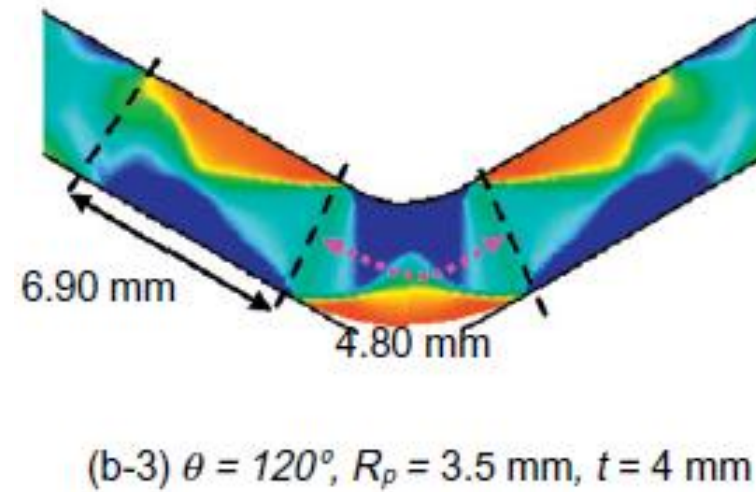
V-die bending: springforward phenomenon

S. Thipprakmas, W. Phanitwong, *Materials and Design* 32 (2011) 4430–4436.

Springback



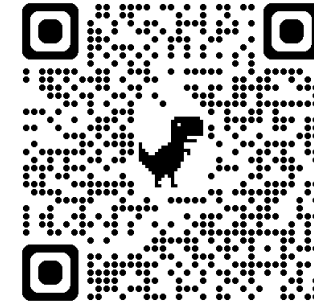
Springforward



Summary

- Higher strains for three-point bending: shorter bending span.
- Effect of strain hardening on deformation during V-die bending:
 - Strain concentration is more severe for DP > CP > QP
 - Strain at bending spine is higher for DP > CP > QP
- Springback angle is higher for CP > DP > QP
- DP and QP experience springforward.

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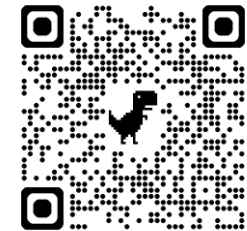


LinkedIn Profile

Thank you!

Relative publications:

N. Mendes-Fonseca, M. Diab, J. Kang, D.S. Wilkinson, **A comparative study on the bendability of a Dual Phase steel: three-point bend versus V-die test**, *J. Mater. Res. Technol.* 36 (2025) 7603-7614. <https://doi.org/10.1016/j.jmrt.2025.05.007>.



N. Mendes-Fonseca, J. Kang, D.S. Wilkinson, **Deformation of Advanced High Strength Steels during V-die Bending**, Submitted to *J. Mater. Res. Technol.*

Q & A:

Please use the Q & A feature to ask your questions



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