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Dortmund, Germany

Exceeding the Forming Limit Curve with Deep Drawing Followed by Electromagnetic Calibration

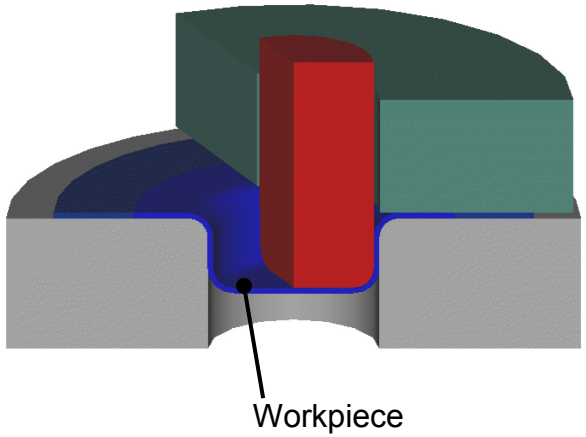
O. Koray Demir

Subject

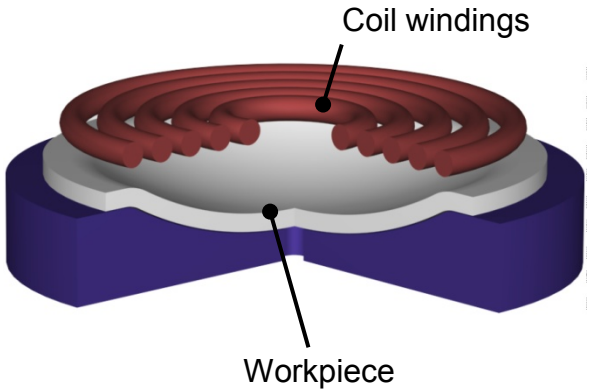
Strains that can be reached by the process chain

composed of

Deep drawing

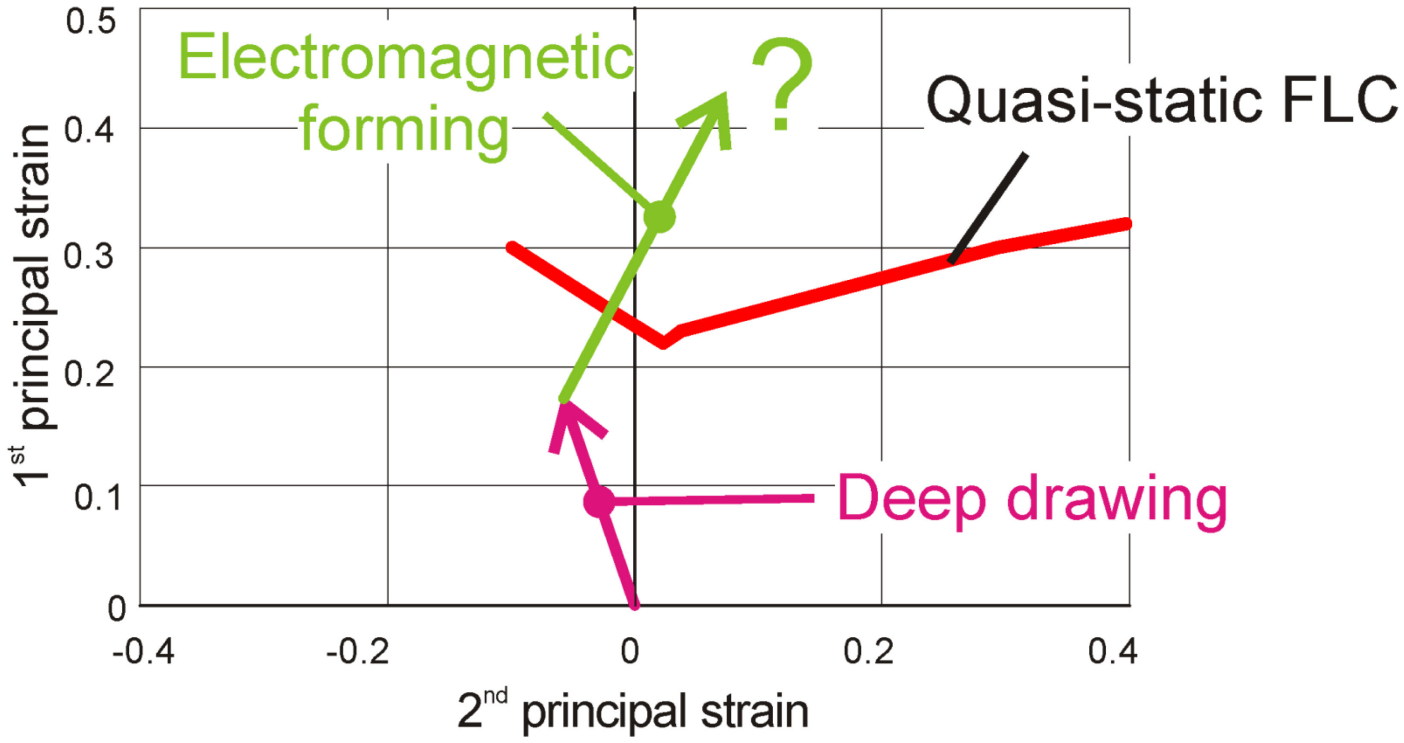


Electromagnetic forming



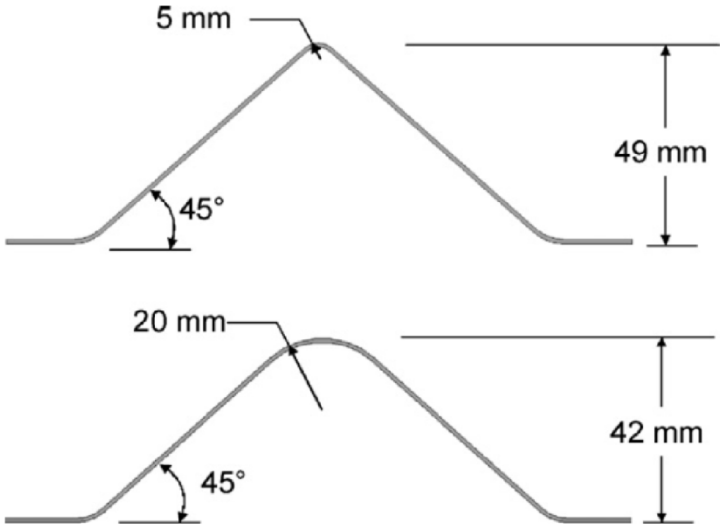
Question

Can the quasi-static FLC be exceeded by the process chain?



Significance of the question

Aim: To understand the increase of process limits in case of such process chains better



We can design and optimize such process chains better

Sources:
Imbert and Worswick; Electromagnetic reduction of a pre-formed radius on AA 5754 sheet, 2011
Liu, Li, and Yu; Numerical modeling and deformation analysis for electromagnetically assisted deep drawing of AA5052 sheet

Content

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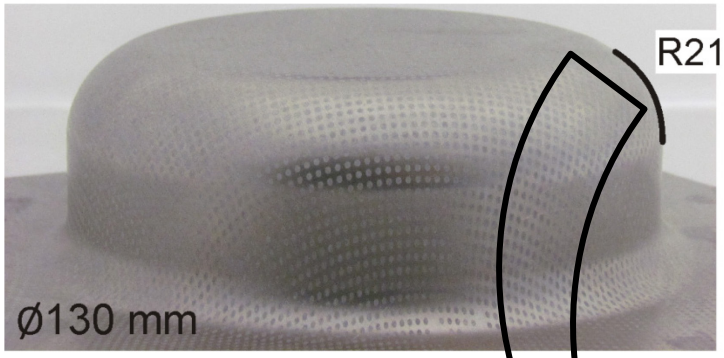
- **Experimental setup**
- Results
  - Deep drawing
  - Electromagnetic calibration
- Discussion
- Conclusion

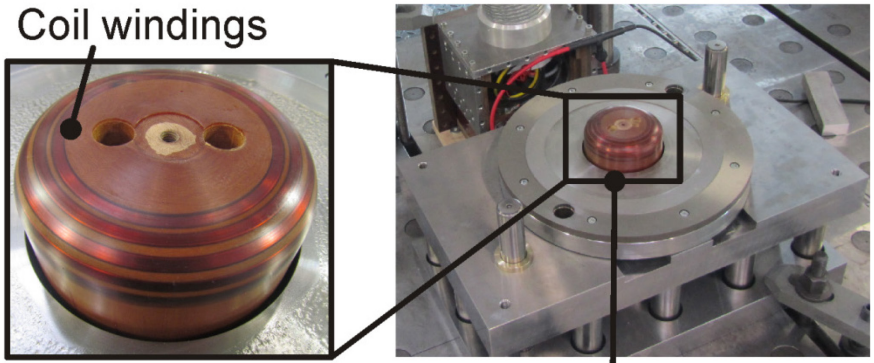
The process chain

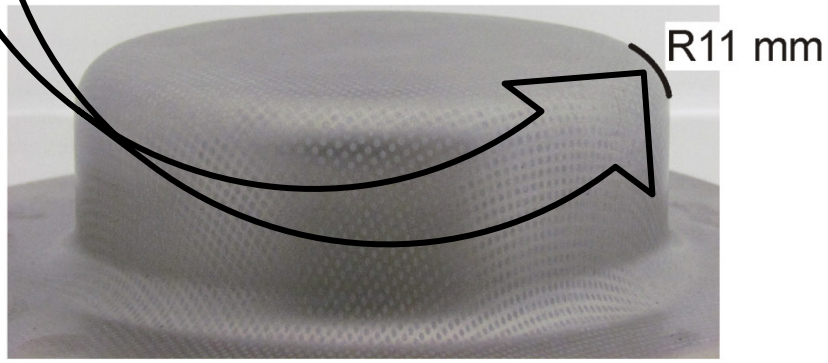
Material: EN AW-5083

Deep drawn cup



Tooling for electromagnetic calibration

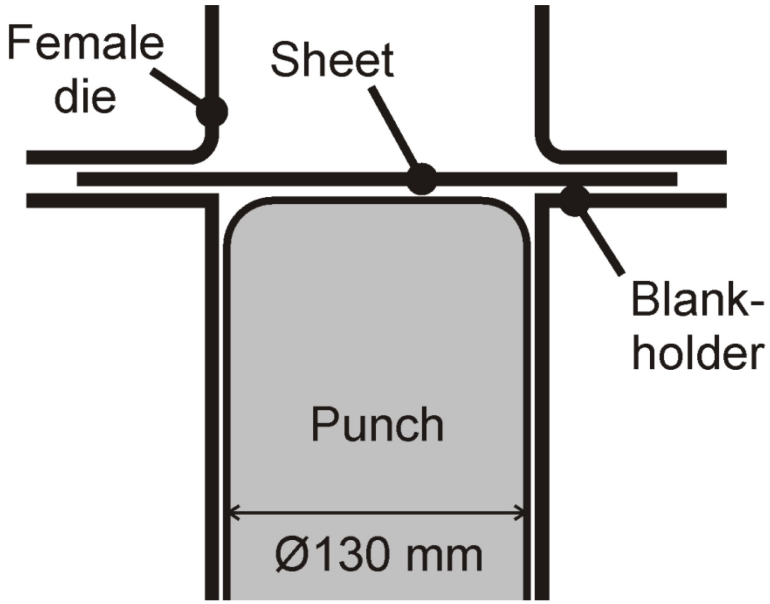




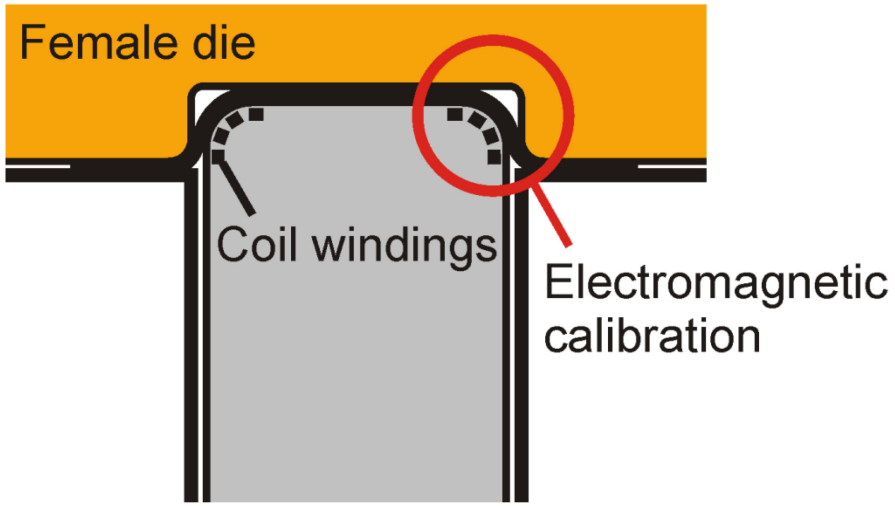
Cup after electromagnetic calibration

The process chain

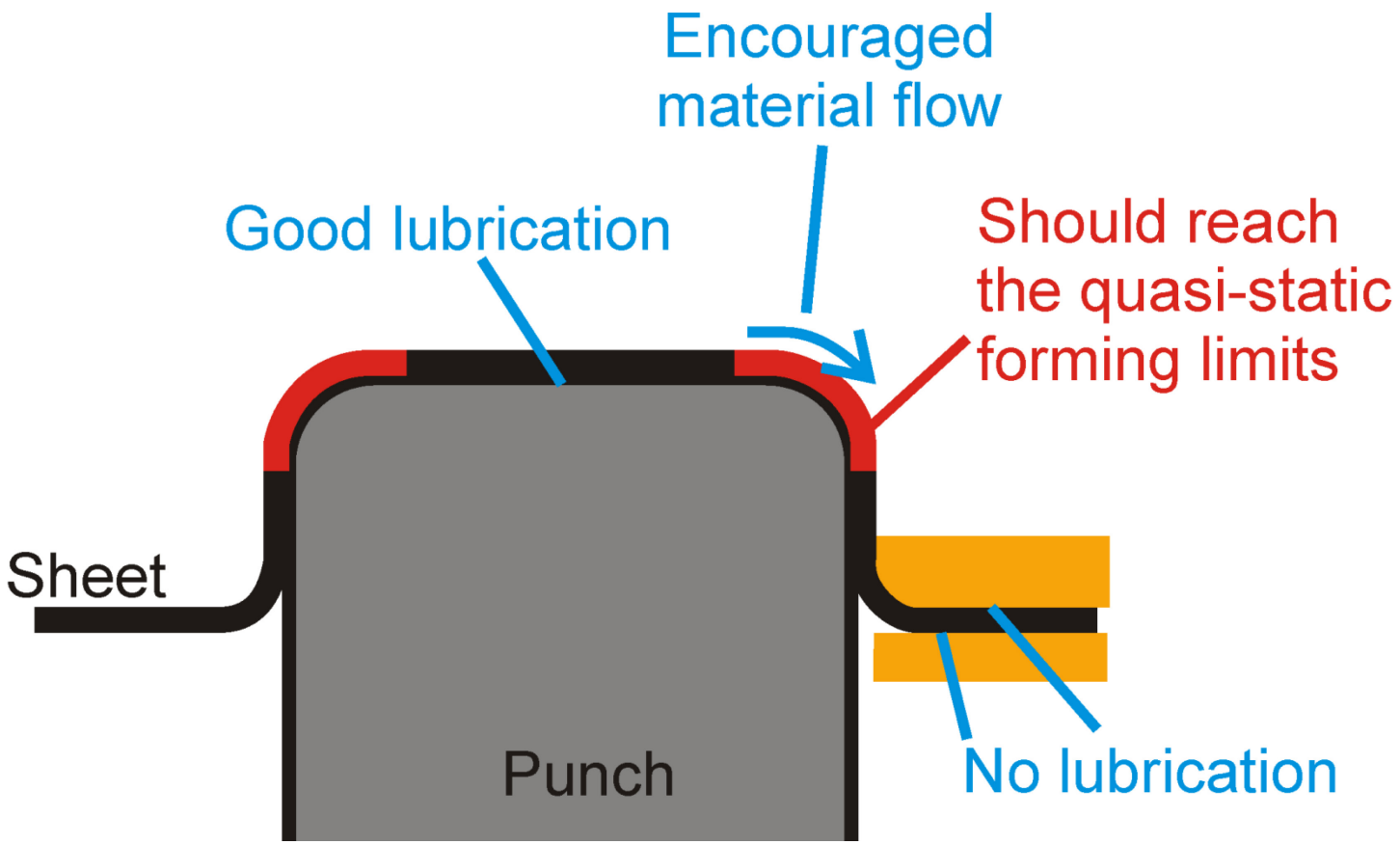
Deep Drawing



Electromagnetic forming



Deep drawing



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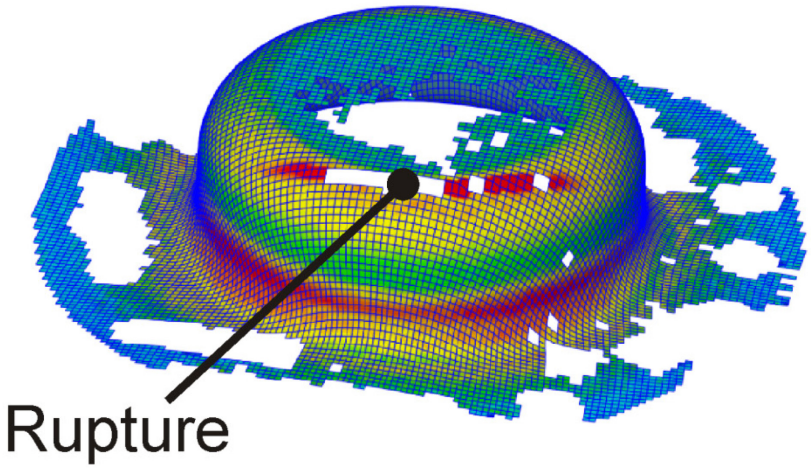
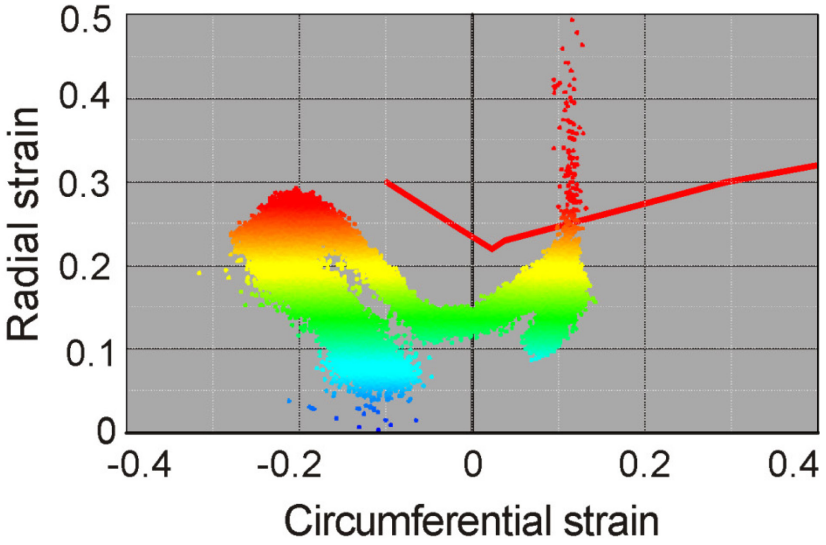
Deep drawing

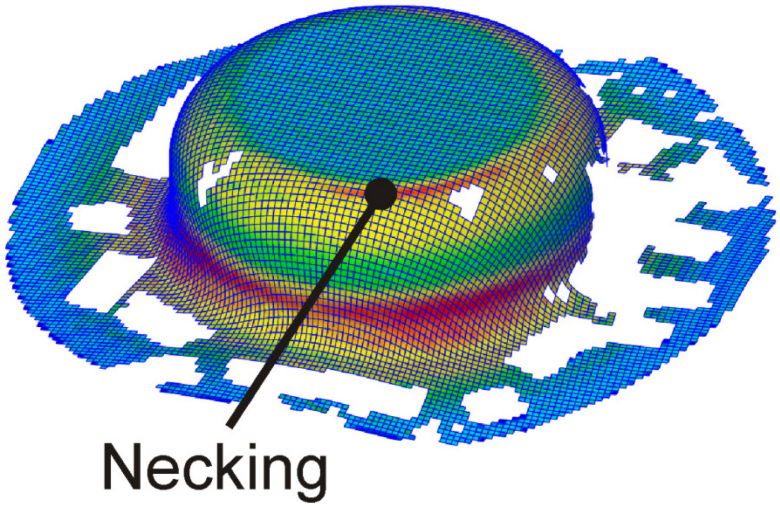
Blankholder force 560 kN

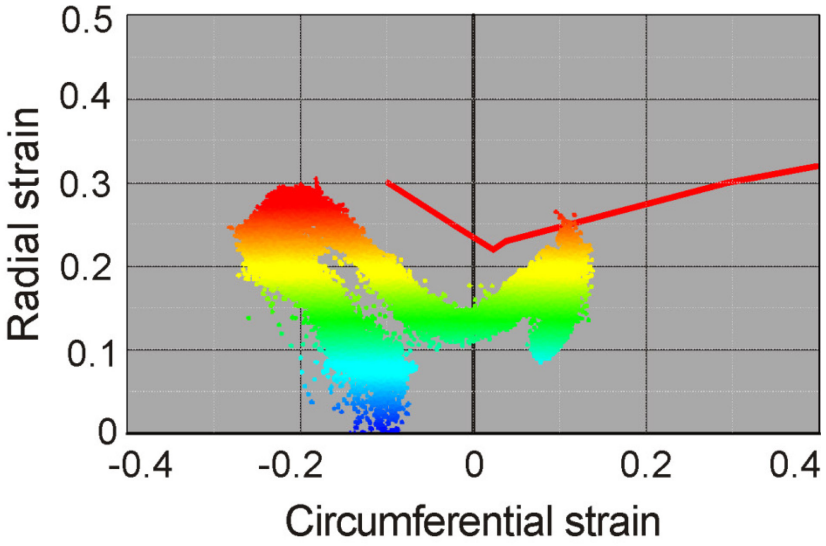




Deep drawing

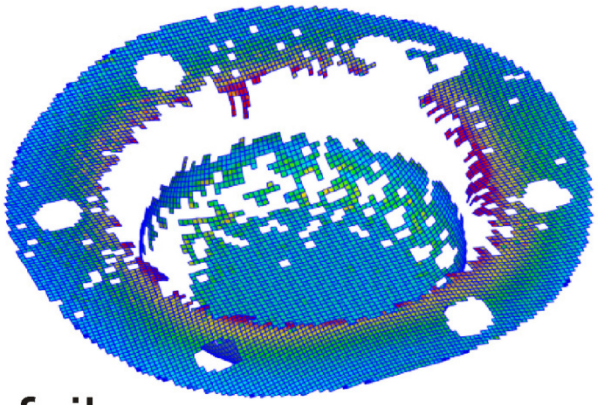
Blankholder force 540 kN



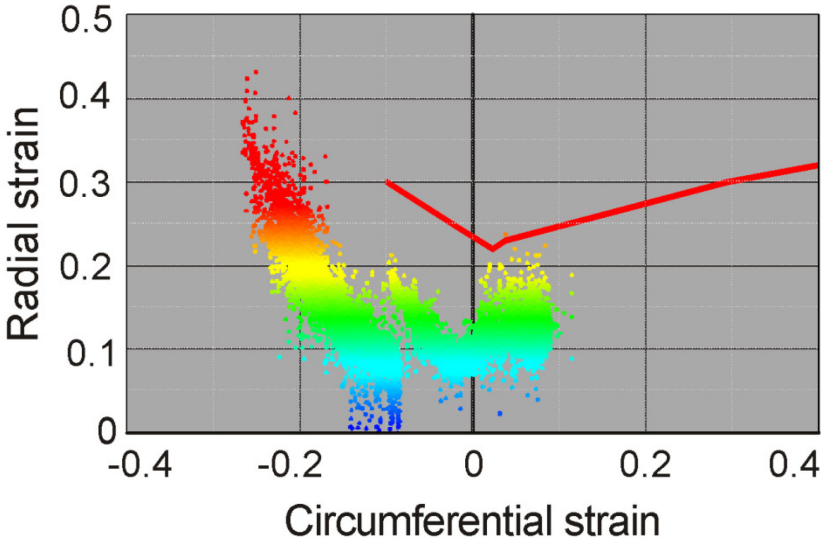


Deep drawing

Blankholder force 520 kN

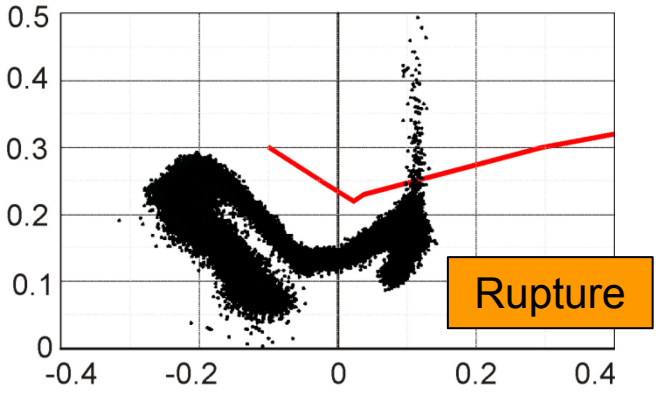


No failure

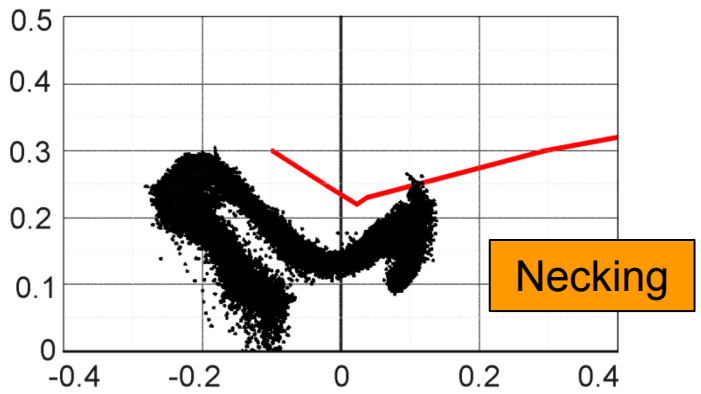


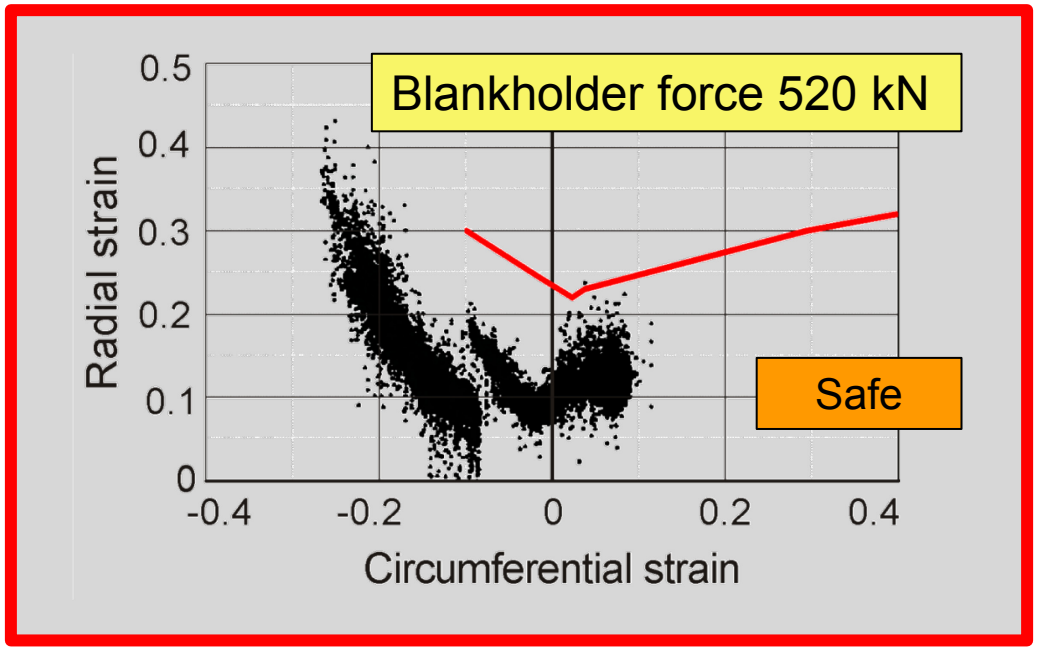
Deep drawing

Blankholder force 560 kN



Blankholder force 540 kN





To be calibrated

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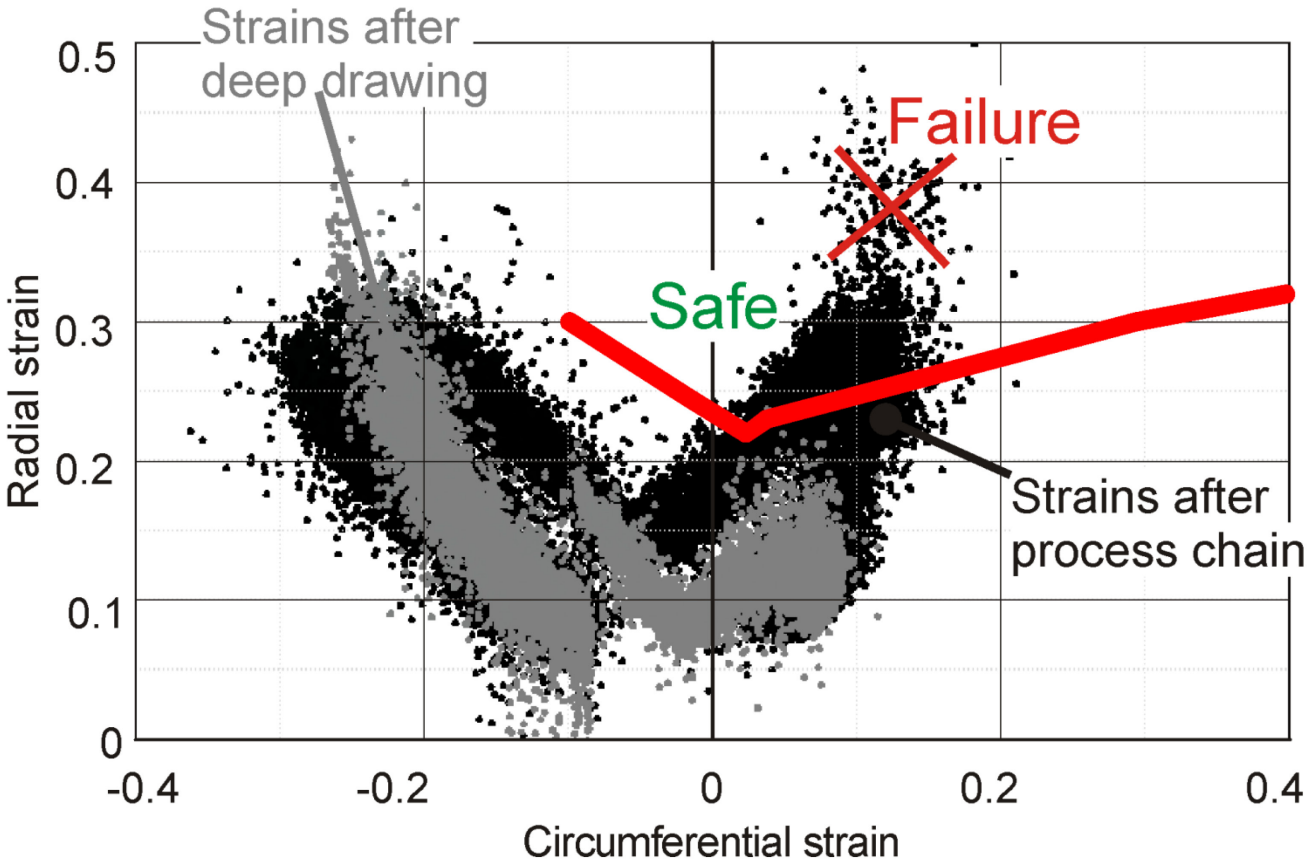
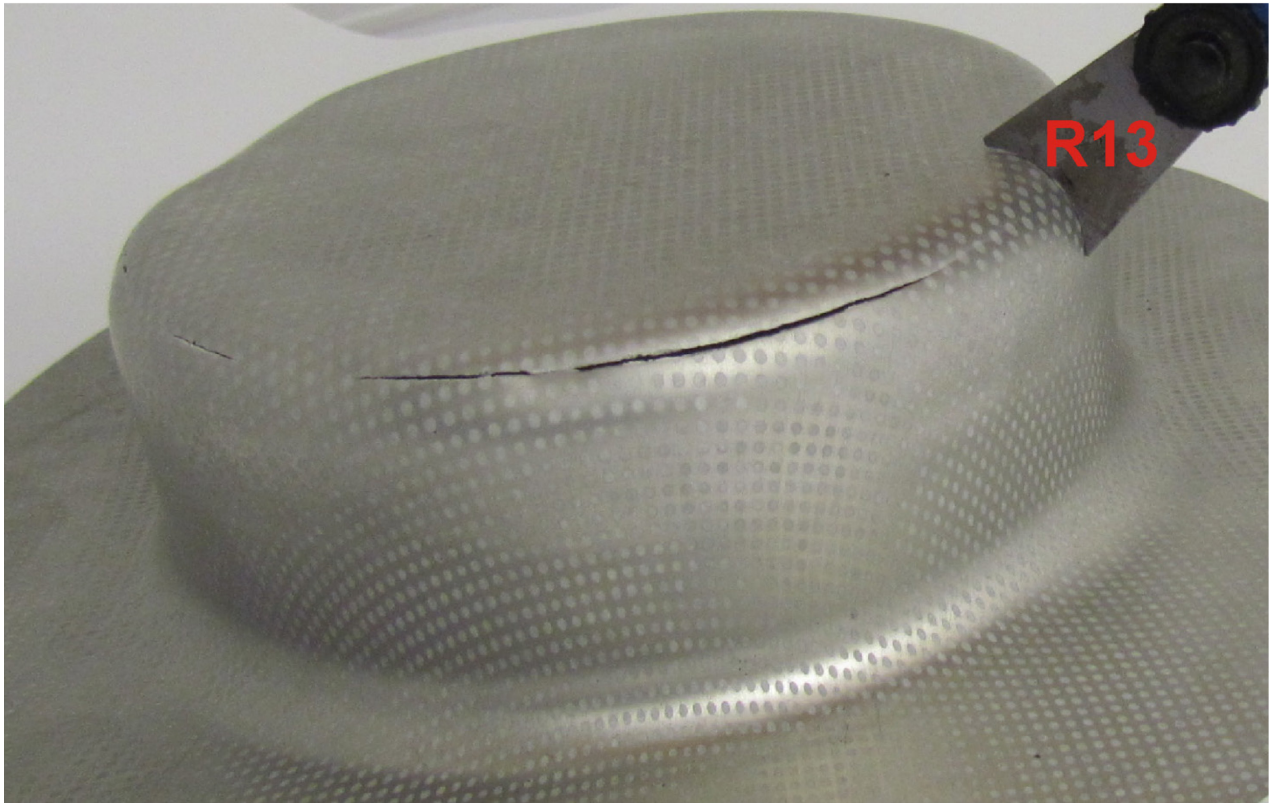
Forming limit diagram after calibration

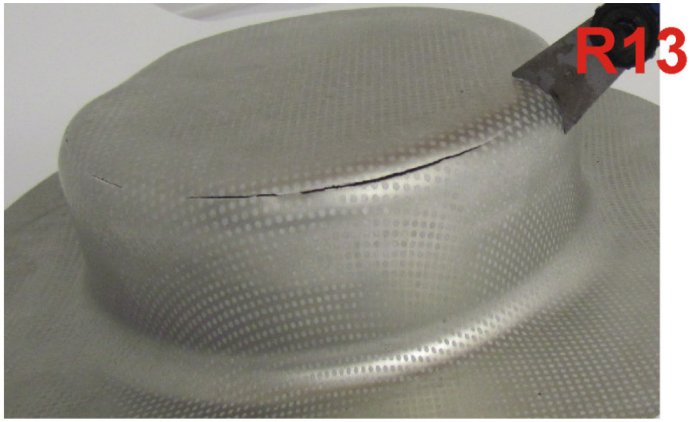


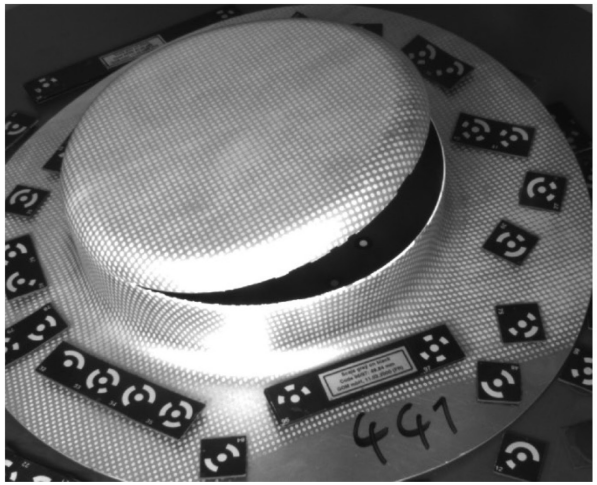
Sharpest radius reached



Sharpest radii reached

Process chain
Drawn to R20
Calibrated to R13





Deep drawing with
R15

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Answer

Quasi-static FLC can be exceeded.

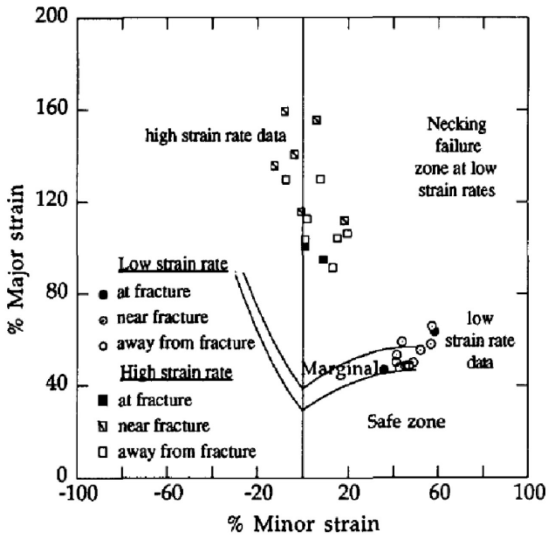
What is the cause?

Impulse forming

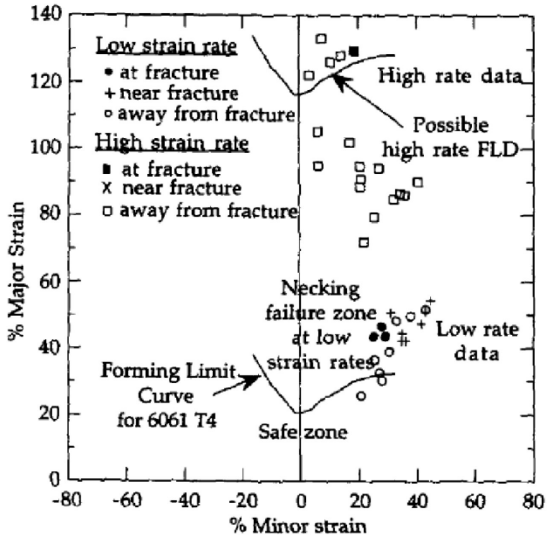
Strain rate *change*

Reason: Impulse forming

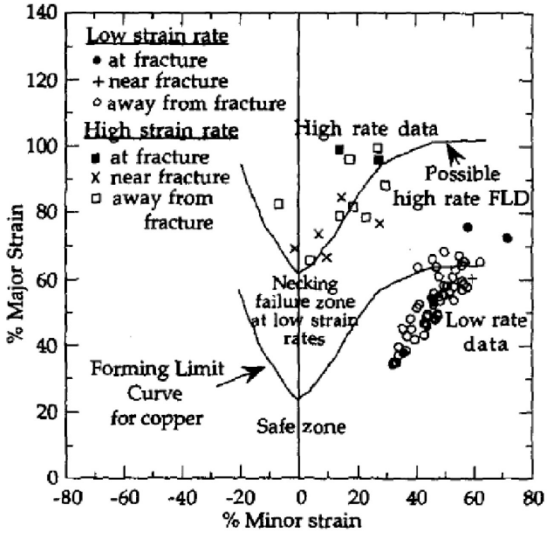
Interstitial free Steel



EN AW-6061 T4

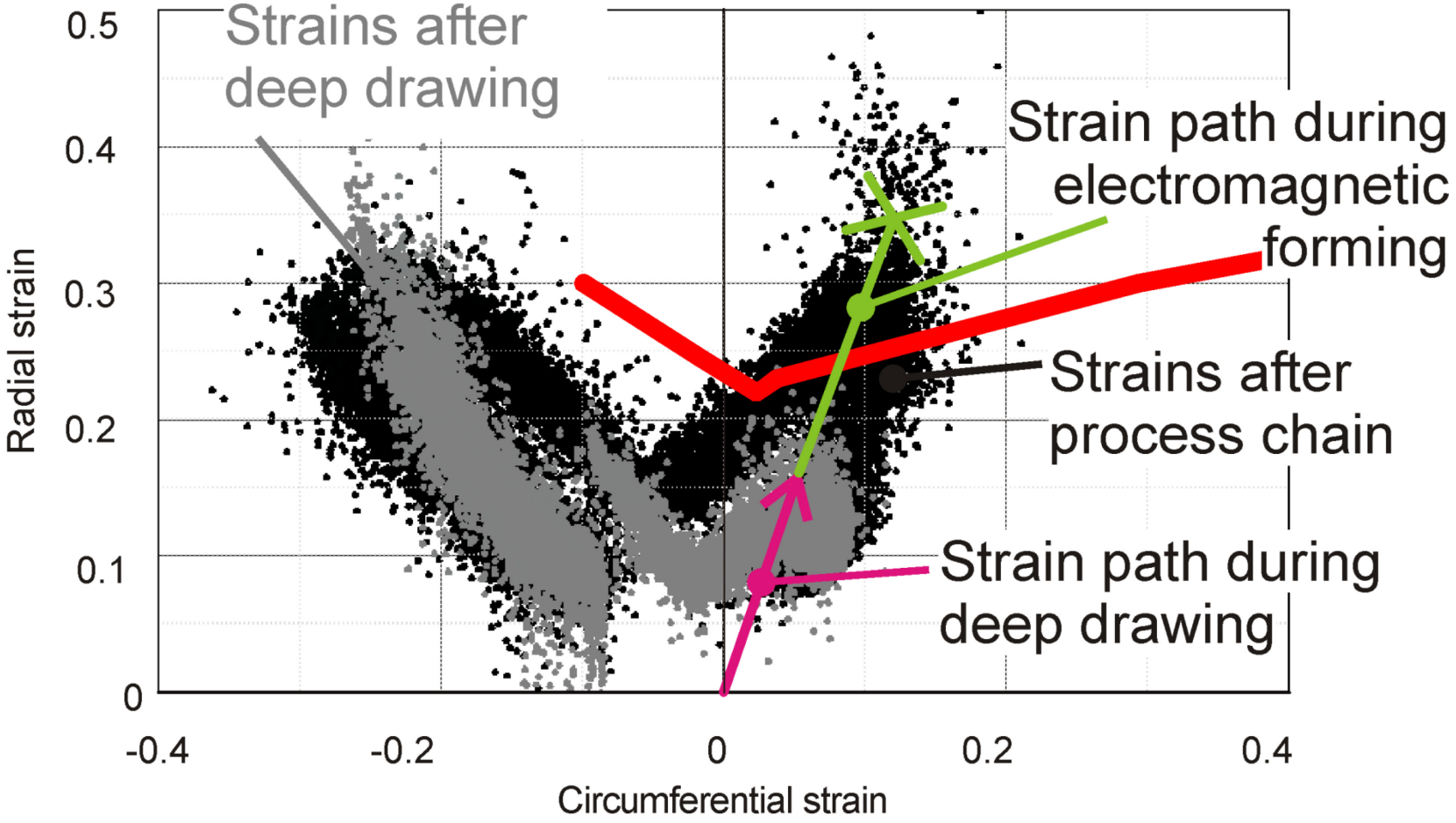


OFHC Copper



Sources:
Balanethiram and Daehn, Enhanced formability of interstitial free iron at high strain rates, 1992
Balanethiram and Daehn, Hyperplasticity: Enhanced formability at high rates, 1994

Reason: Strain rate change



Reasons

The factor causing the extension of quasi-static FLC:

Impulse forming

Strain rate change

?

Further research is needed!

Extending limits of deep drawing

Process chain extends the forming limits of deep drawing

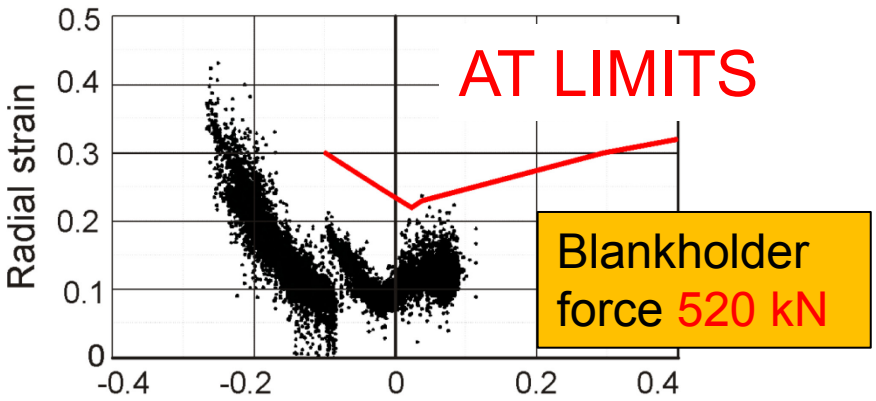
Evidences:

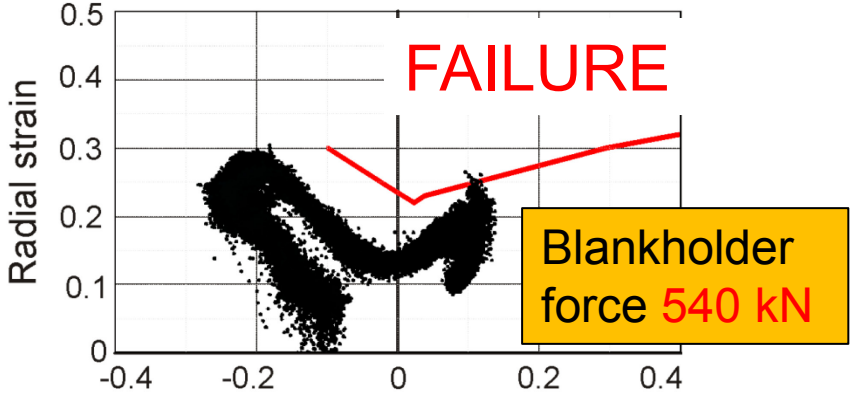
Part at the forming limits can be calibrated

The calibrated part cannot be produced by deep drawing

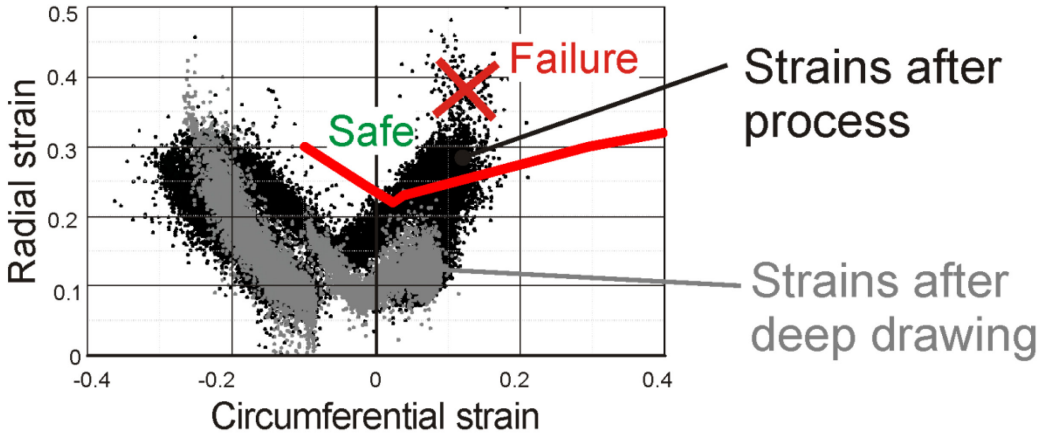
Extending limits of deep drawing

Part, which was formed until the process limits can be formed further electromagnetically



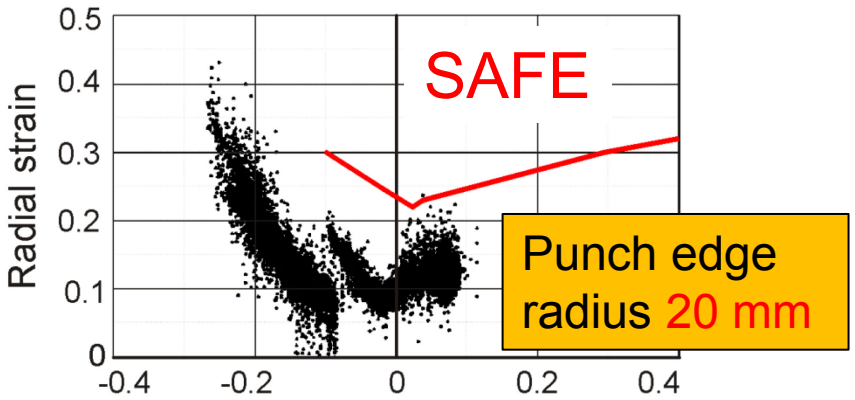


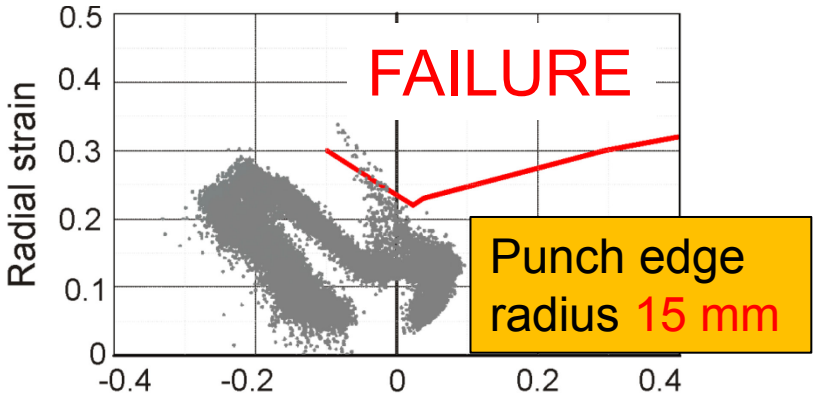
Electromagnetic calibration



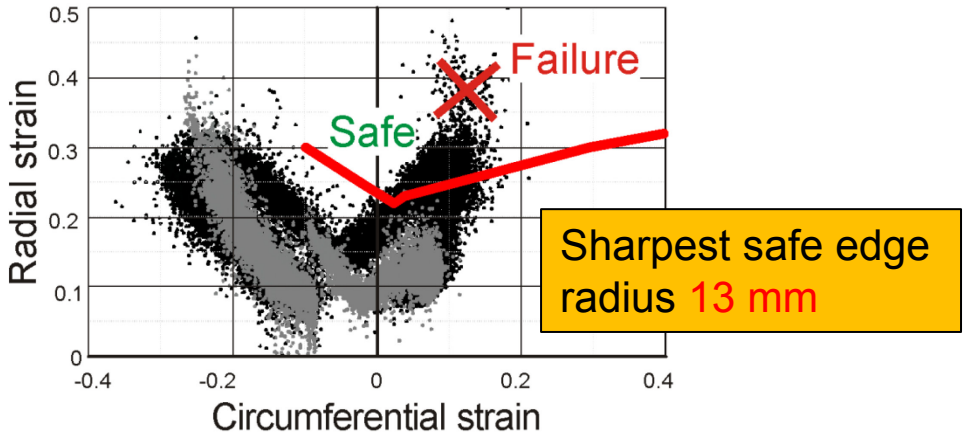
Extending limits of deep drawing

The calibrated part cannot be produced by deep drawing





Electromagnetic calibration



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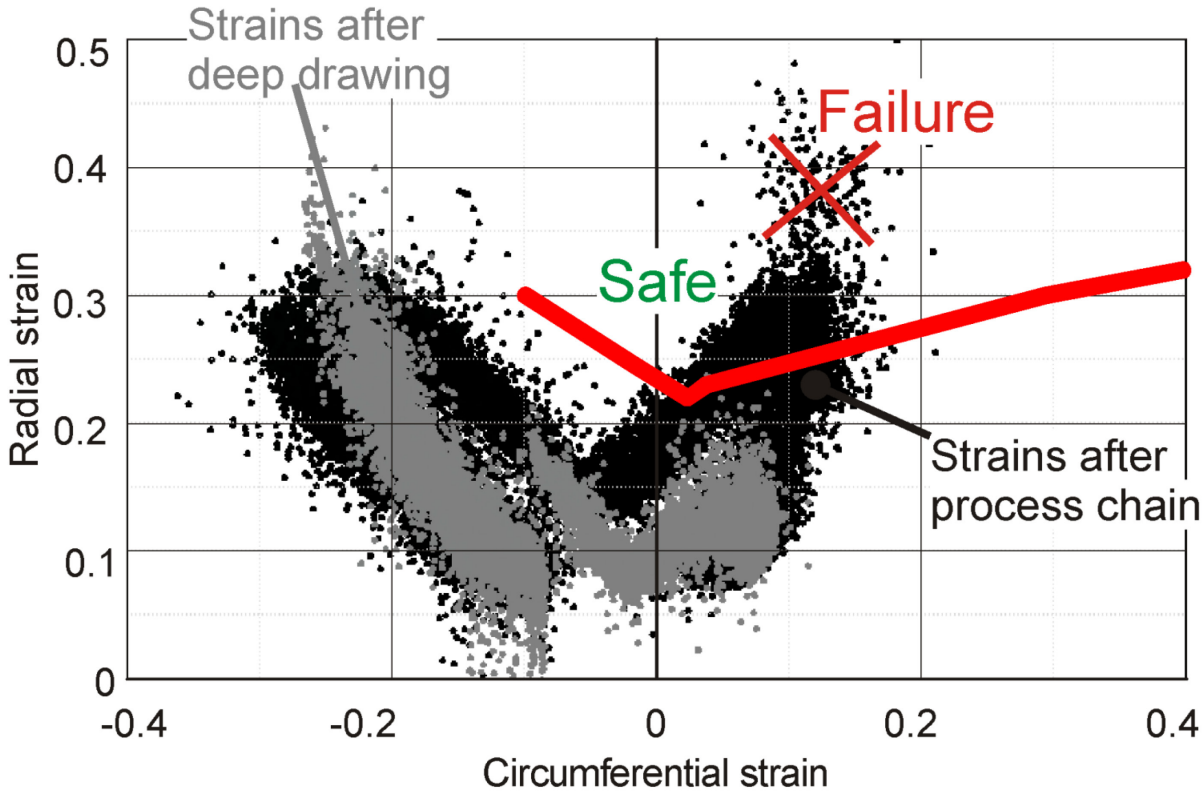
Conclusion

Quasi-static FLC can be exceeded by the process chain



Conclusion

Quasi-static FLC can be exceeded by the process chain

Further research is needed to determine the factor(s) causing this

The process chain extends the forming limits of deep drawing

THANK YOU FOR YOUR ATTENTION!