Detection of the Onset of Necking and Accurate Measurement of Strain Limits of AHSS

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Acknowledgements

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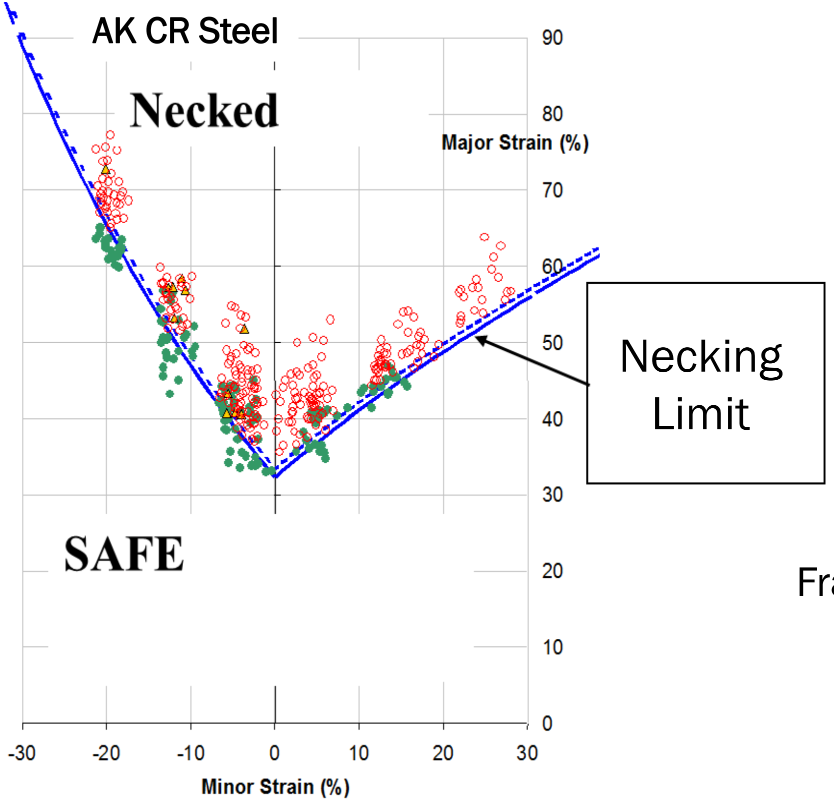
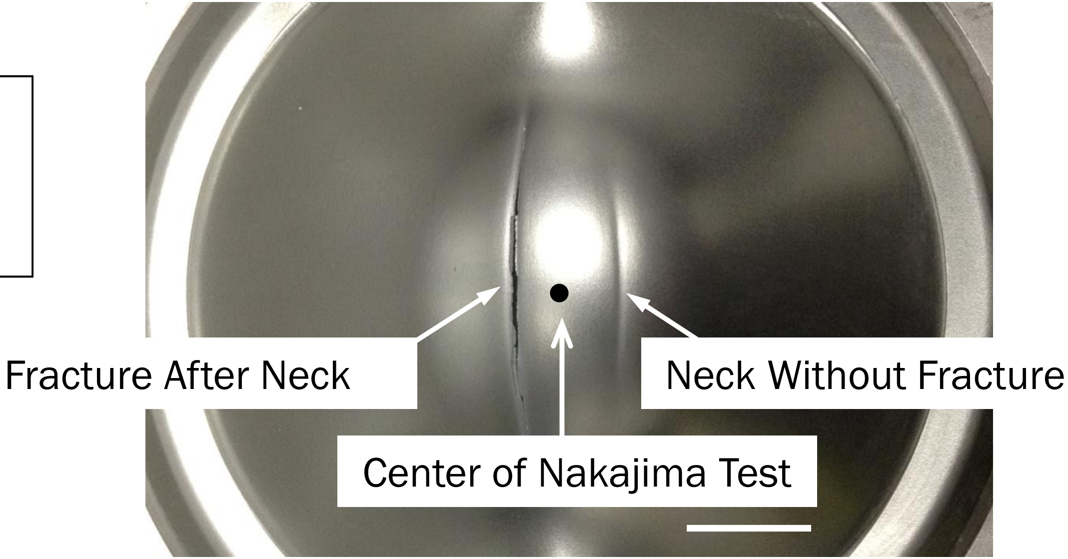
What is a Neck?

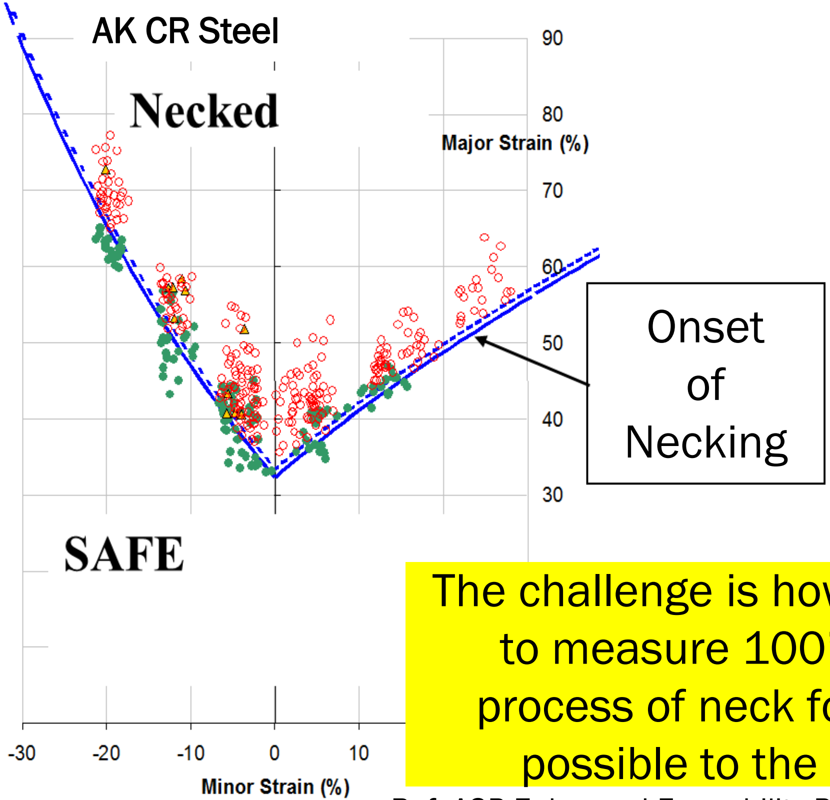


A neck is a groove that may develop during plastic deformation that deepens and may lead to fracture during the stamping process.



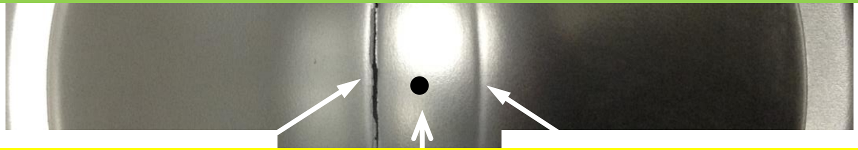
Ref: ASP Enhanced Formability Project, 2003.

What is Onset of Necking?



Onset of necking is defined to be the condition at a neck becomes detectable by tactile or visible sensing of the groove of the neck.

The condition of the onset of necking is important to know because localized necking is an unacceptable manufacturing condition.

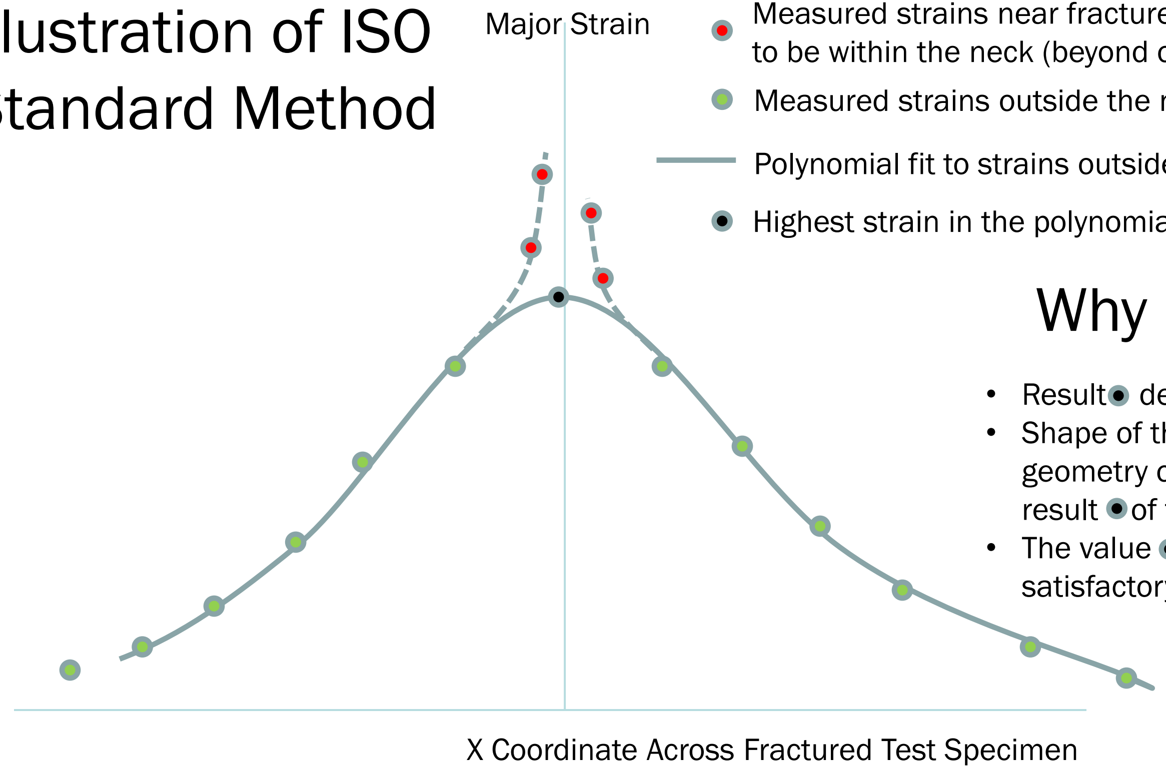


The challenge is how to measure the onset of necking without having to measure 100's of test results over a range of severity in the process of neck formation to find a few tests that are as close as possible to the condition to qualify as at the onset of a neck.

Ref: ASP Enhanced Formability Project, 2003

A Popular but Flawed Idea

Illustration of ISO Standard Method



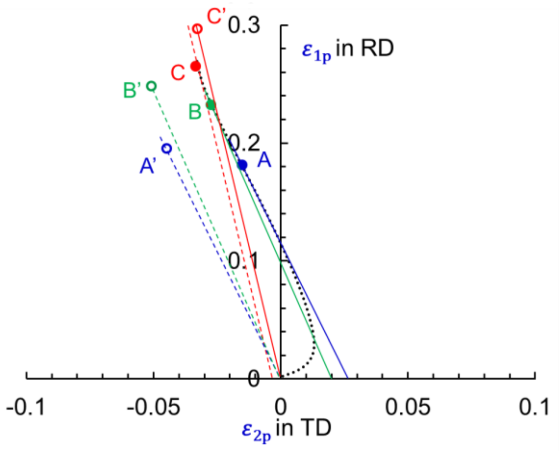
- Measured strains near fractured edge identified to be within the neck (beyond onset of necking)
- Measured strains outside the neck
- Polynomial fit to strains outside the neck
- Highest strain in the polynomial fit

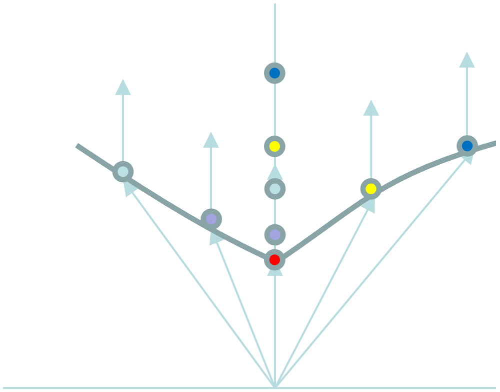
Why is this flawed?

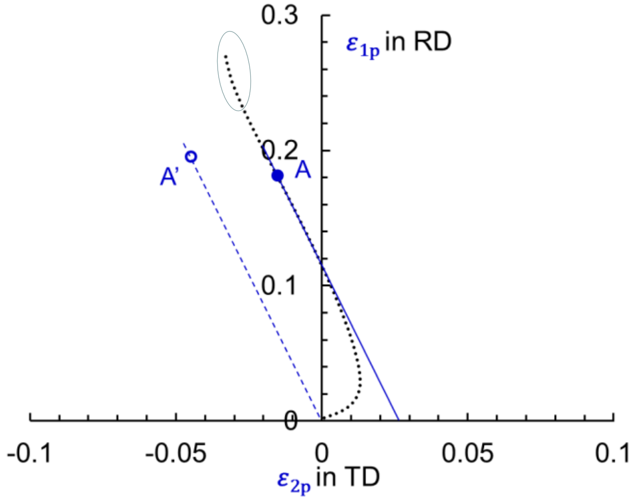
- Result depends on the order of the polynomial.
- Shape of the strain distribution depends on the geometry of the tooling and the blank, and therefore the result of the fit with be affected by this.
- The value might be in the ballpark… it might even be a satisfactory conservative limit, but is that good enough?

Another Reason Onset of Necking is Important

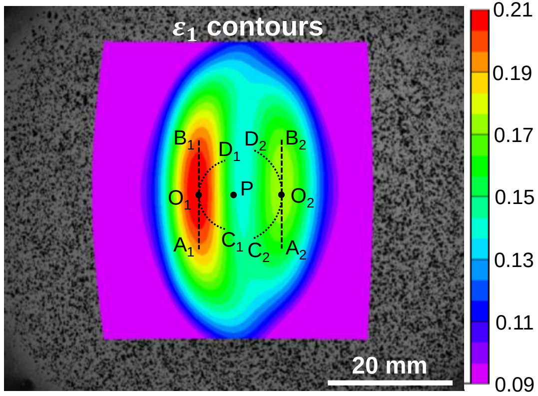
Correction for Nonlinear Strain Path

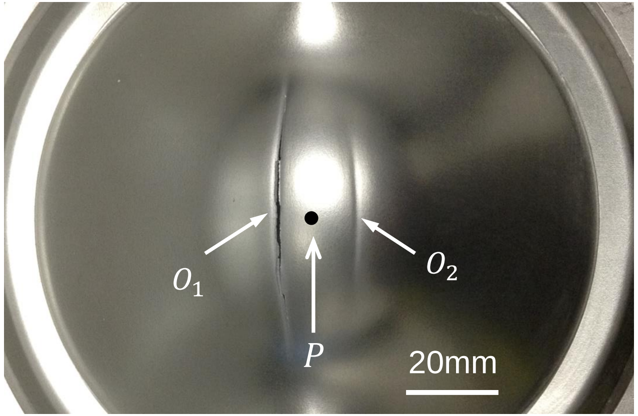






DIC Offers Insight Into the Onset of Necking

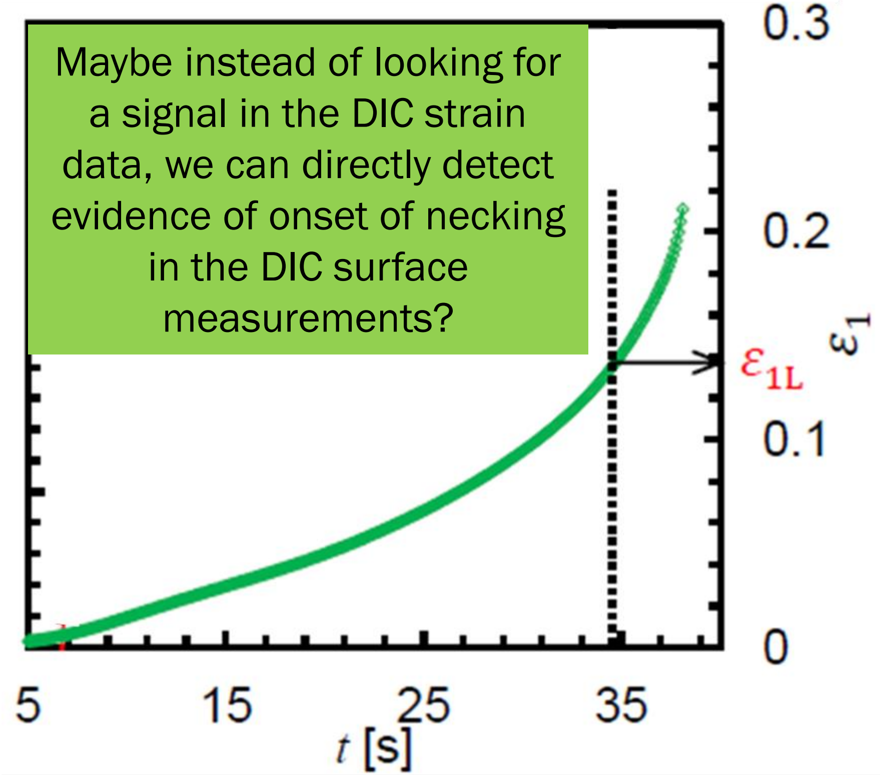




- Strain shows localization
- Complete history of strain and strain rates
- Visible groove in the DIC shaded surface image

DIC Strain History Data

Maybe instead of looking for a signal in the DIC strain data, we can directly detect evidence of onset of necking in the DIC surface measurements?



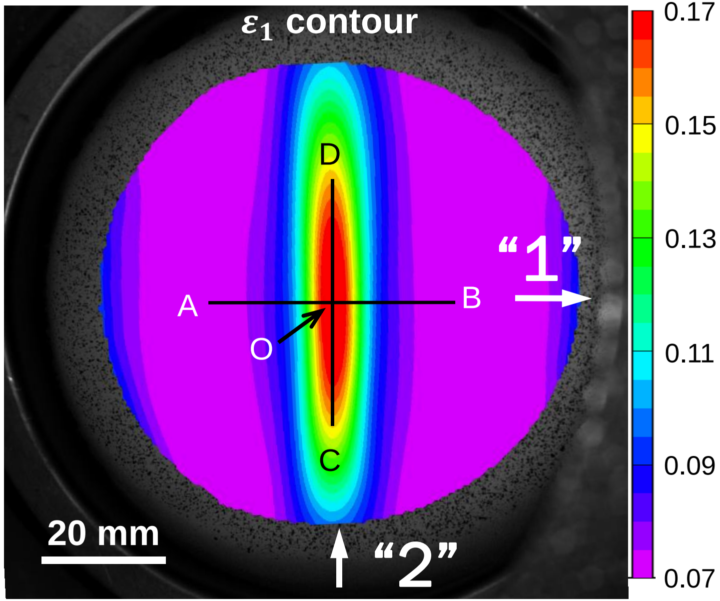
Many researchers believe that the DIC recorded strain history can be used to determine onset of necking.

Clearly the record of these strains show an increase in the strain rate as the test approaches fracture.

But strain acceleration also results from inhomogeneous straining, even if a neck does not form.

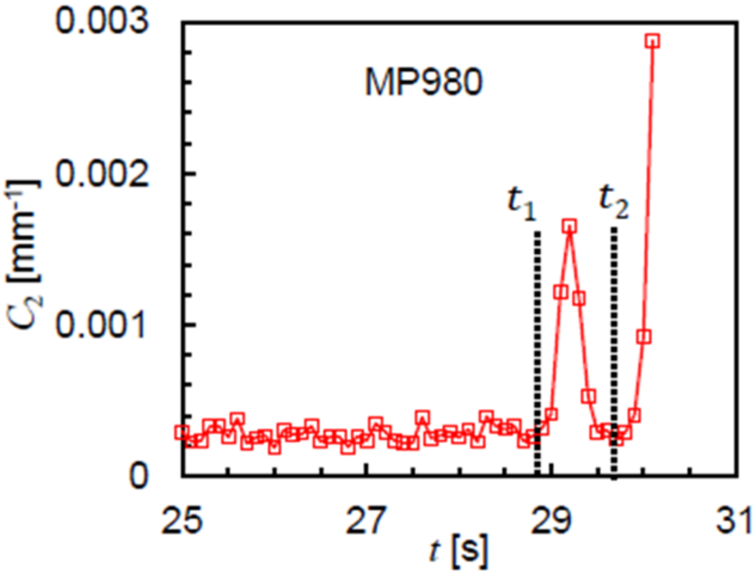
How does one de-convolute a strain signal from localized neck groove from other factors?

Marciniak Test (Cylindrical Punch 100 mm D)

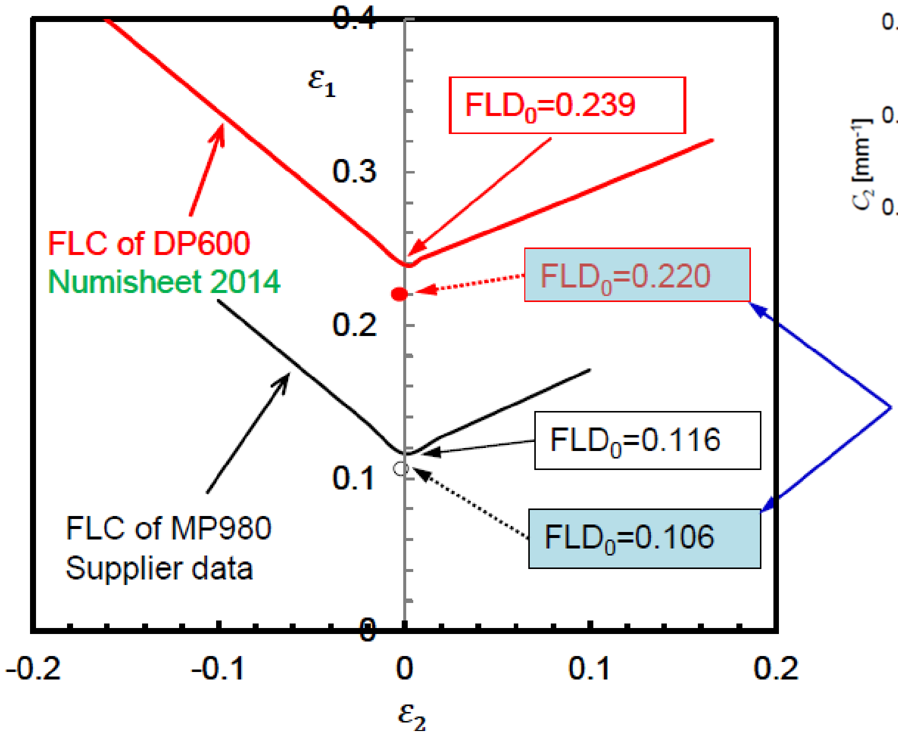


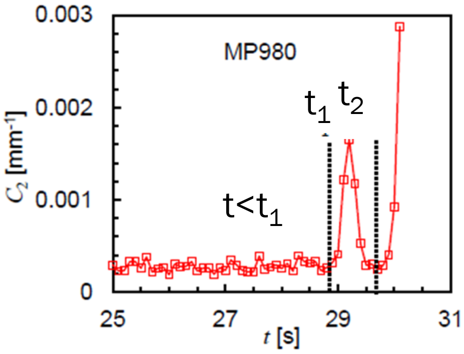
Selected points along the line CD that would eventually form the neck and later fracture

Fit these points to a circle to determine the curvature C_2

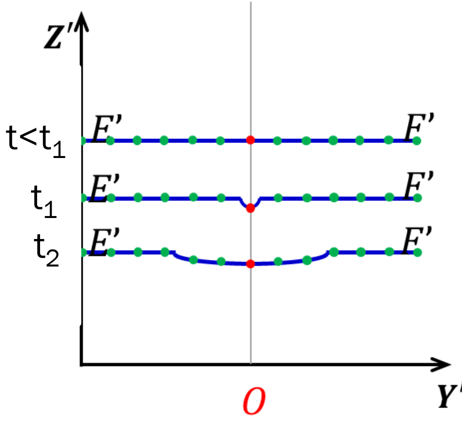


The Pulse in Curvature Initiates at a Strain Just Below Known FLCs





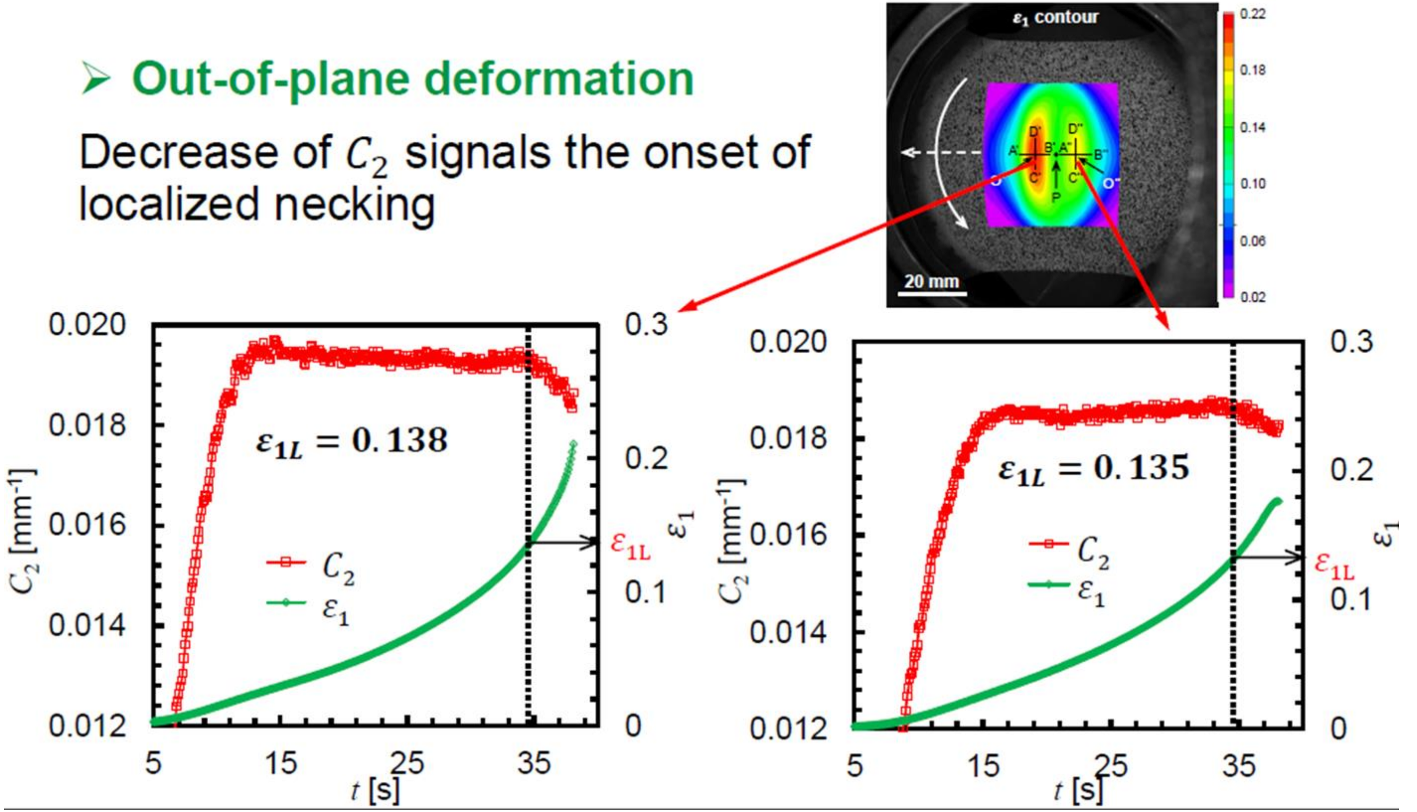
Interpretation of the pulse



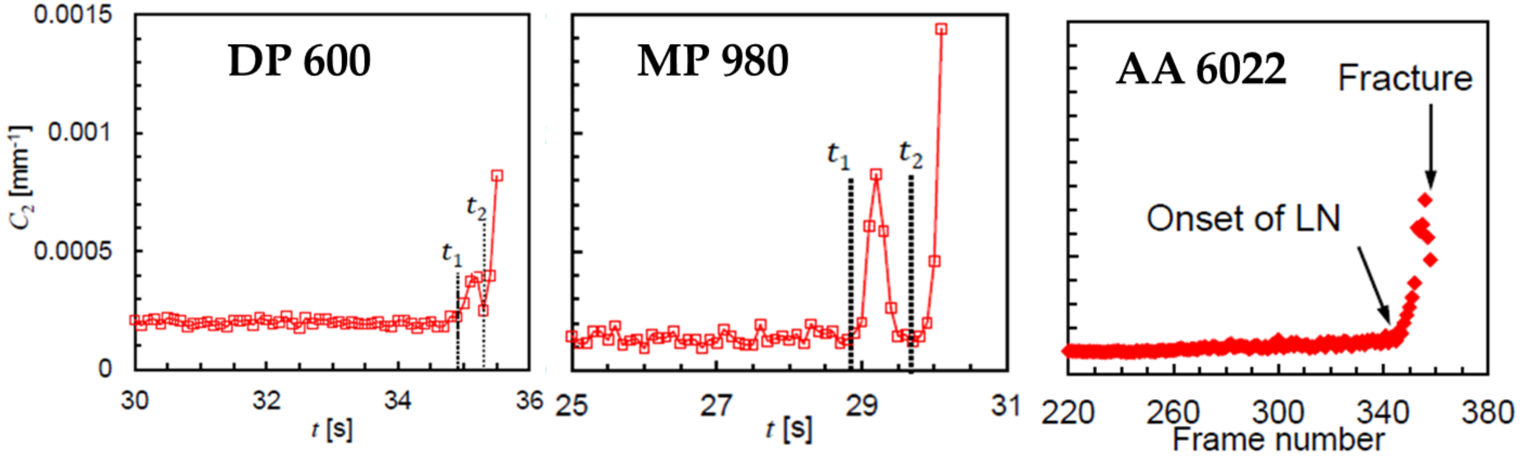
Nakajima Curvature Signal is Different

- **Out-of-plane deformation**

Decrease of C_2 signals the onset of localized necking

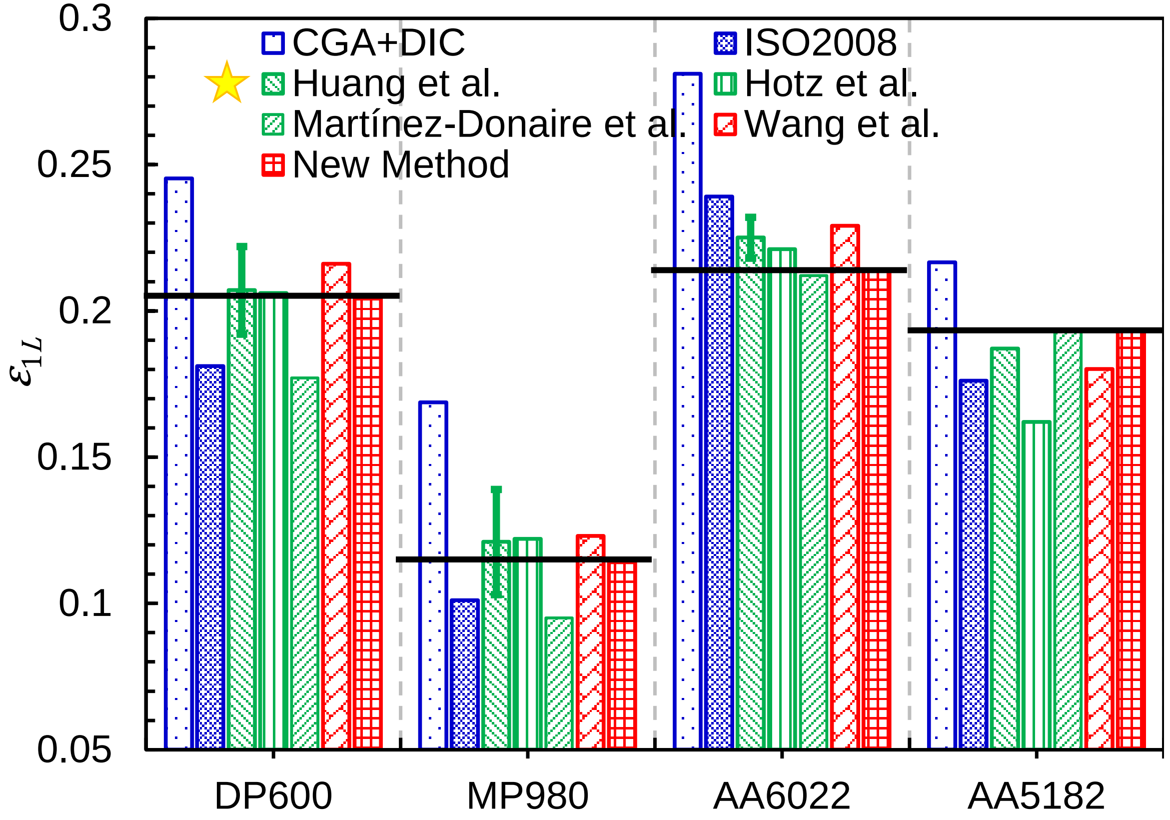


Signal Observed in Every Metal Tested



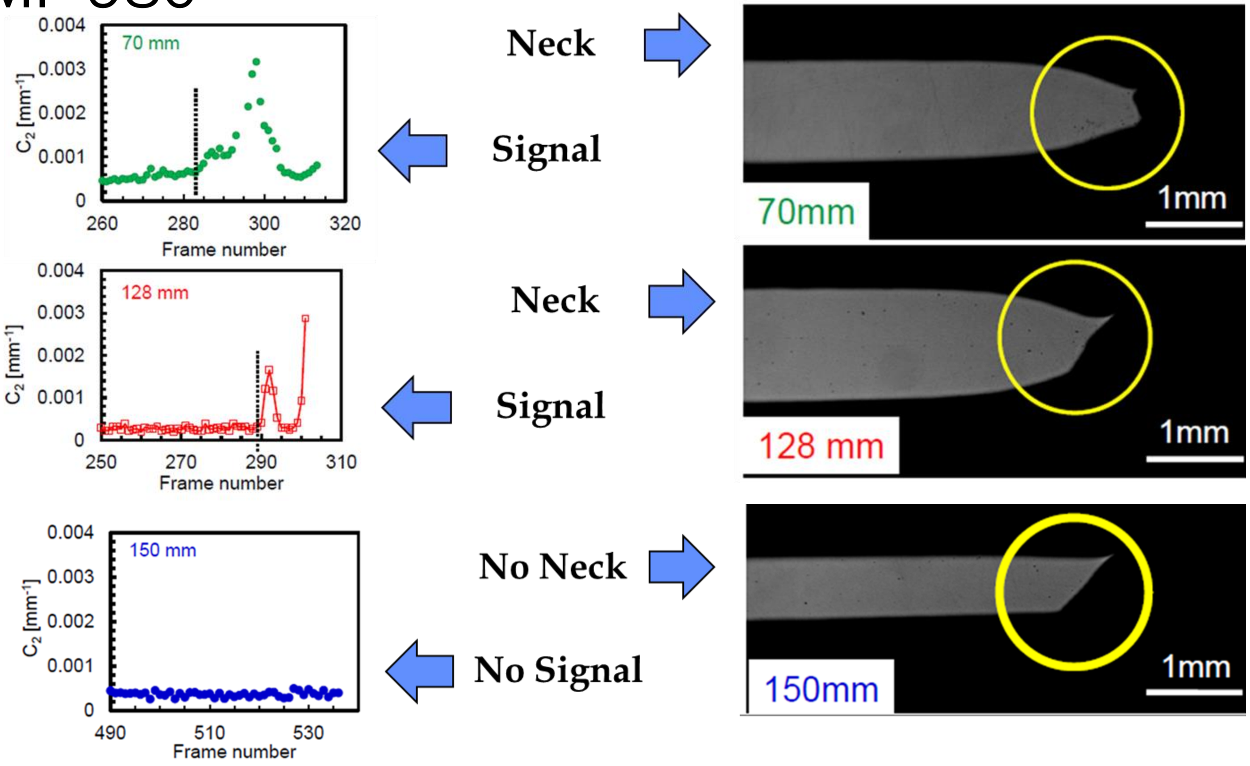
	DP600	MP980 QP980	Four 1180 steels	AA5182	AA6022	Two other AA6xxx
Nakazima	√	√	√	√	√	√
Marciniak	√	√	√	√	√	Not tested

Comparison to Other Methods

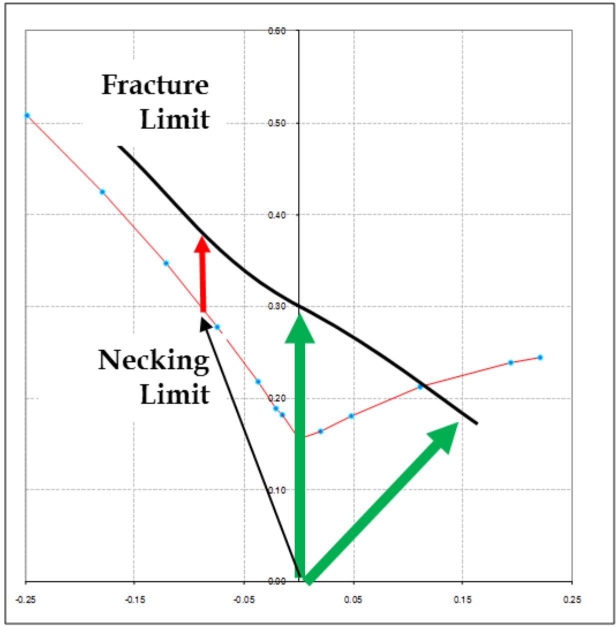


Further Insight Using this Method

MP 980



Interpretation



Reference

An improved curvature method of detecting the onset of localized necking in Marciniak tests and its extension to Nakazima tests

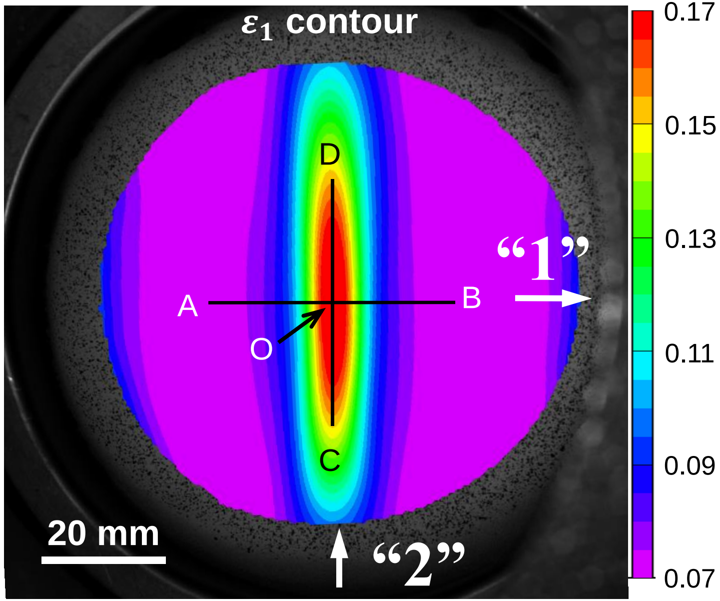
Junying Min, Thomas B. Stoughton, John E. Carsley, Jianping Lin

International Journal of Mechanical Sciences, 2017, **123**, 238-252

Challenges and Solutions

Challenges	Solutions
Fitting to conditions near zero curvature.	Add an artificial curve to data to avoid zero.
Marciniak and Nakajima test signals are different.	Redefine Nakajima surface data to a spherical coordinate system using radius and arc length.
Selection of the data to follow the groove.	A) Expand the analysis to cover the area of the groove. B) Adopt the approach proposed by the University of Waterloo (Warswick, et al.).

University of Waterloo Approach



Selected points along the line AB

Do a running fit to the local curvature in each frame

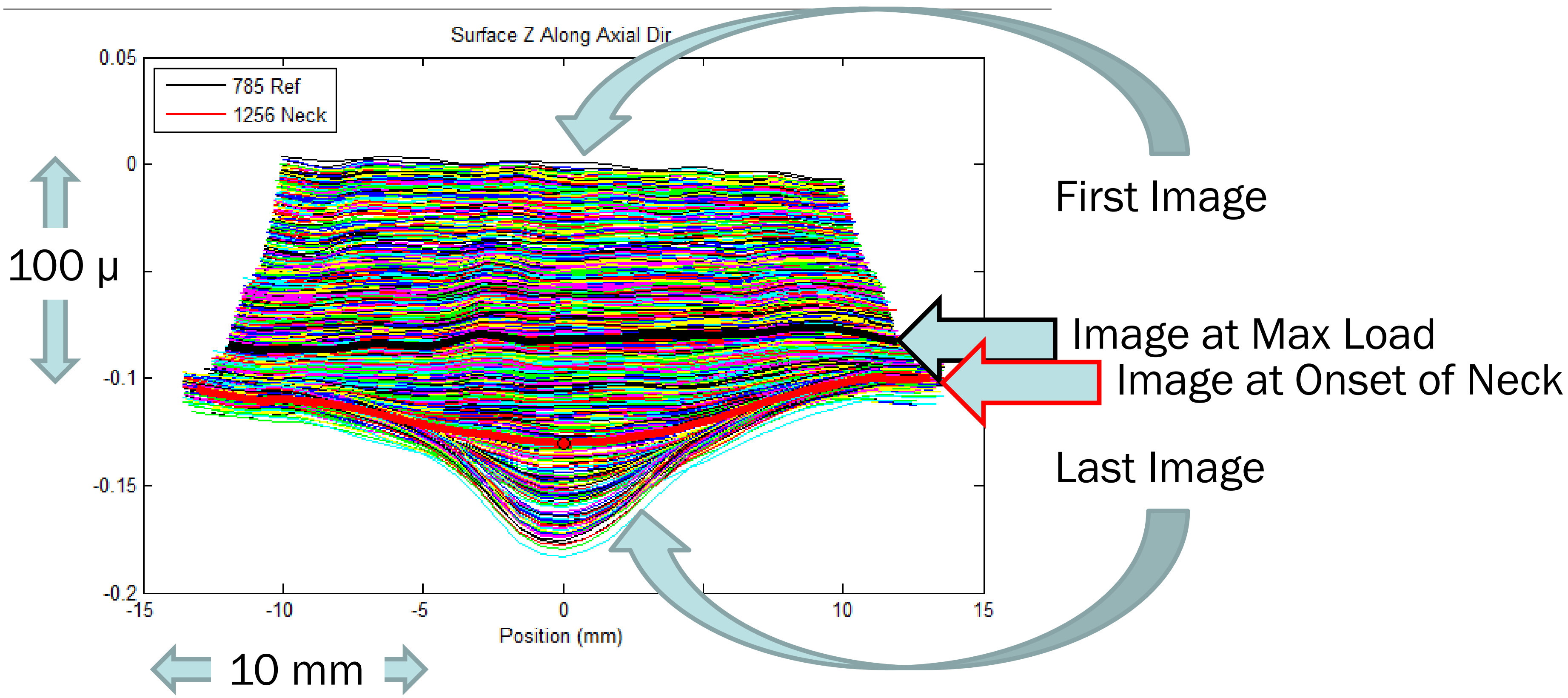
Look for evidence of a groove in the curvature profile

Advantages:
Insensitive to the alignment of the line with the groove

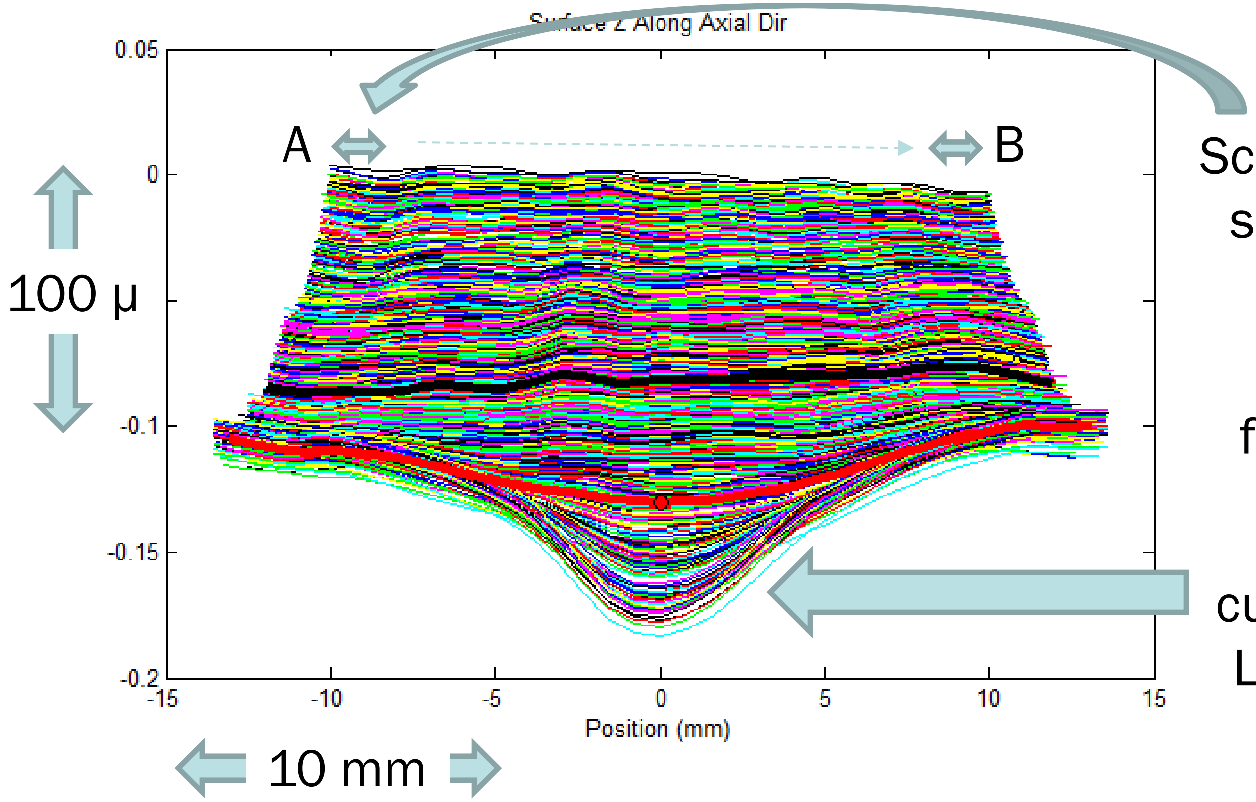
Insensitive to the geometry of the tooling

Extendable to bulge and uniaxial tests

What the AB Sections Look Like for a Uniaxial Tension Test



What the Sections Look Like for a Uniaxial Tension Test

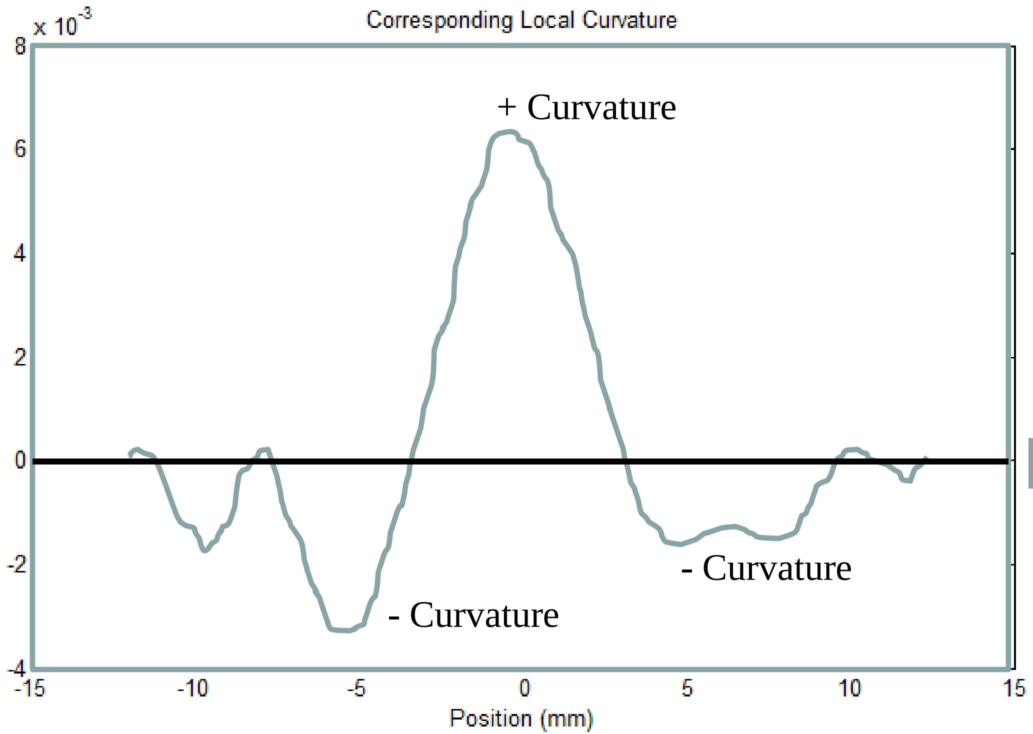


Scale of local curvature fit is set to 1.5 times the sheet thickness

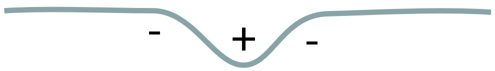
Run the curvature fit from A to B for each frame

Let's look at what these curvature fits look like in the LAST frame before fracture

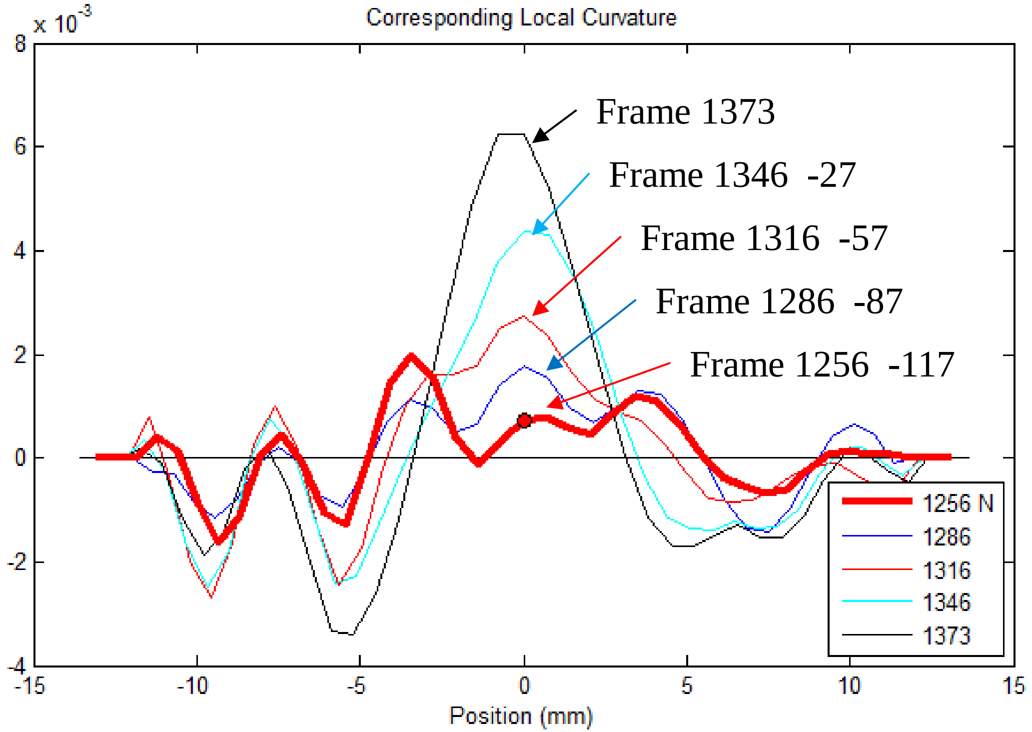
Last Frame Image (#1373) Before Fracture



This data shows characteristics expected for a deep groove



What Does This Groove Look Like in Earlier Frames?



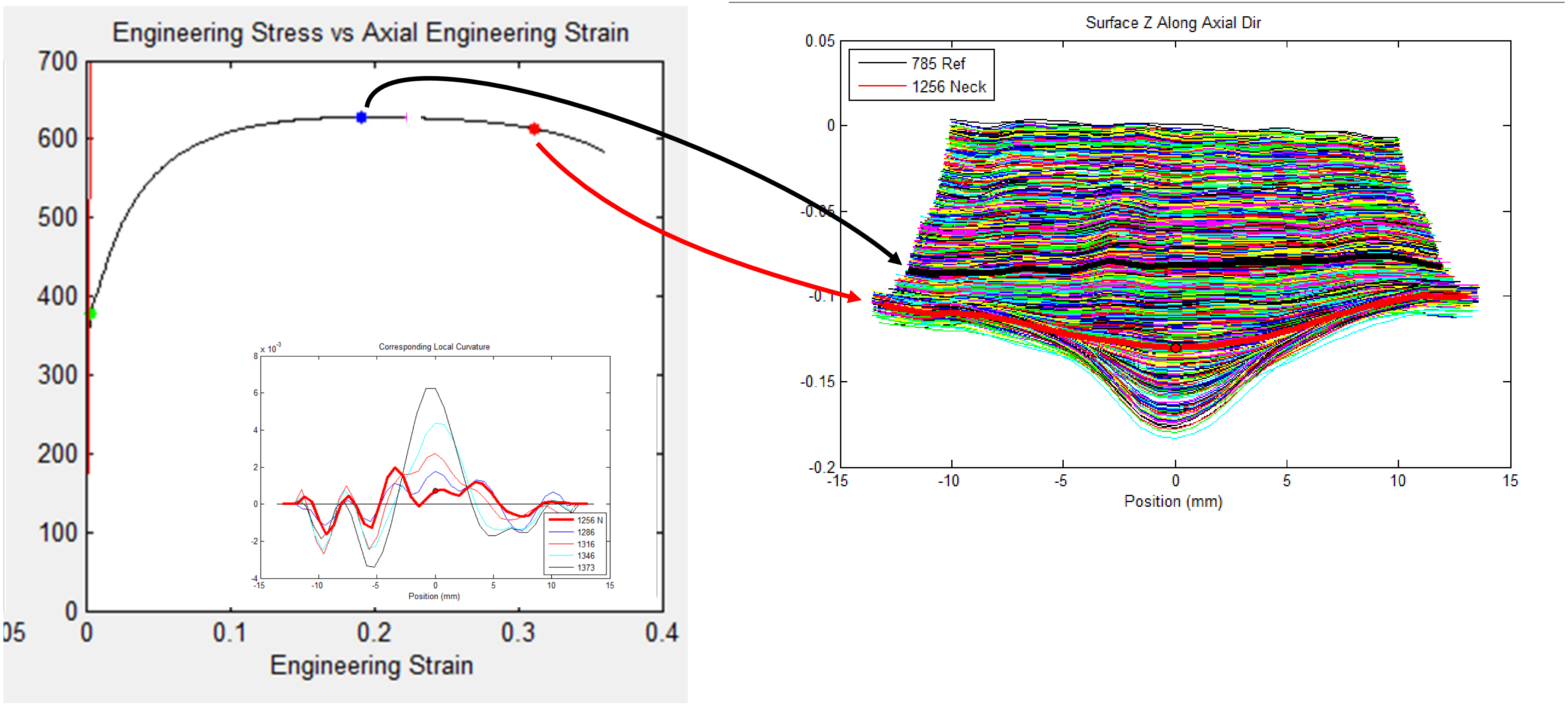
Going back in time the peak curvature gets smaller and smaller.

For the first time looking backward, at frame #1256, the magnitude of the curvature at the location of the groove falls below the average RMS of the curvatures calculated in that frame.

In other words, the signal is lost in the noise.

Can we interpret this to be the start of the neck?

Where This Frame Occurs on the Stress-Strain Curve



Recommend Industry Standard

Focus on the geometry of the DIC surface data to detect the true onset of necking.

Do not support the ad-hoc strain analyses proposed in Europe and current ISO Standards.

This focus on meaningful measurements will enable us to make wider use of AHSS's by taking more advantage of their limited ductility through more reliable knowledge of their actual limits.

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