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U. S. Steel

AN EXPERIMENTAL STUDY ON SHEAR FRACTURE OF ADVANCED HIGH STRENGTH STEELS

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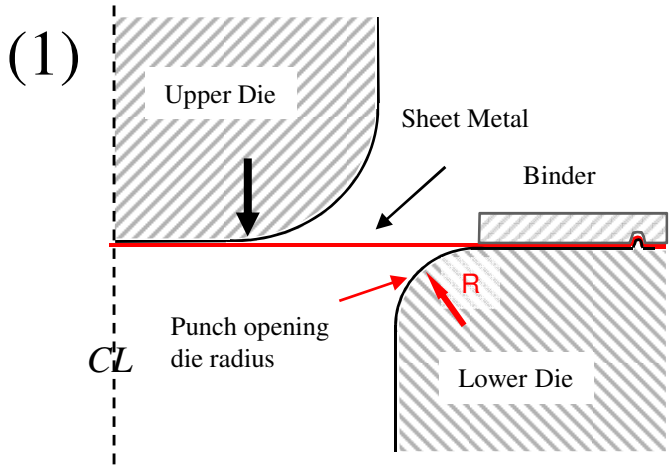
Outline

- Shear Fracture in Stamping and Lab Simulative Test
- Bending Under Tension (BUT) Test
- Stretch Forming Simulator (SFS) Test
- Effects of Forming Variables
- Effects of Material Orientations
- Summary

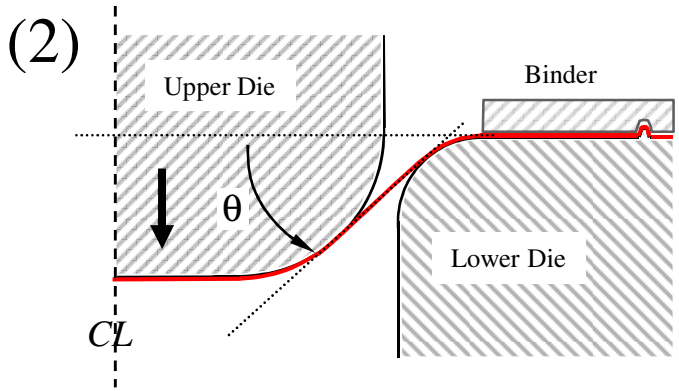
Shear Fracture In Stamping and Lab Simulative Test

U. S. Steel

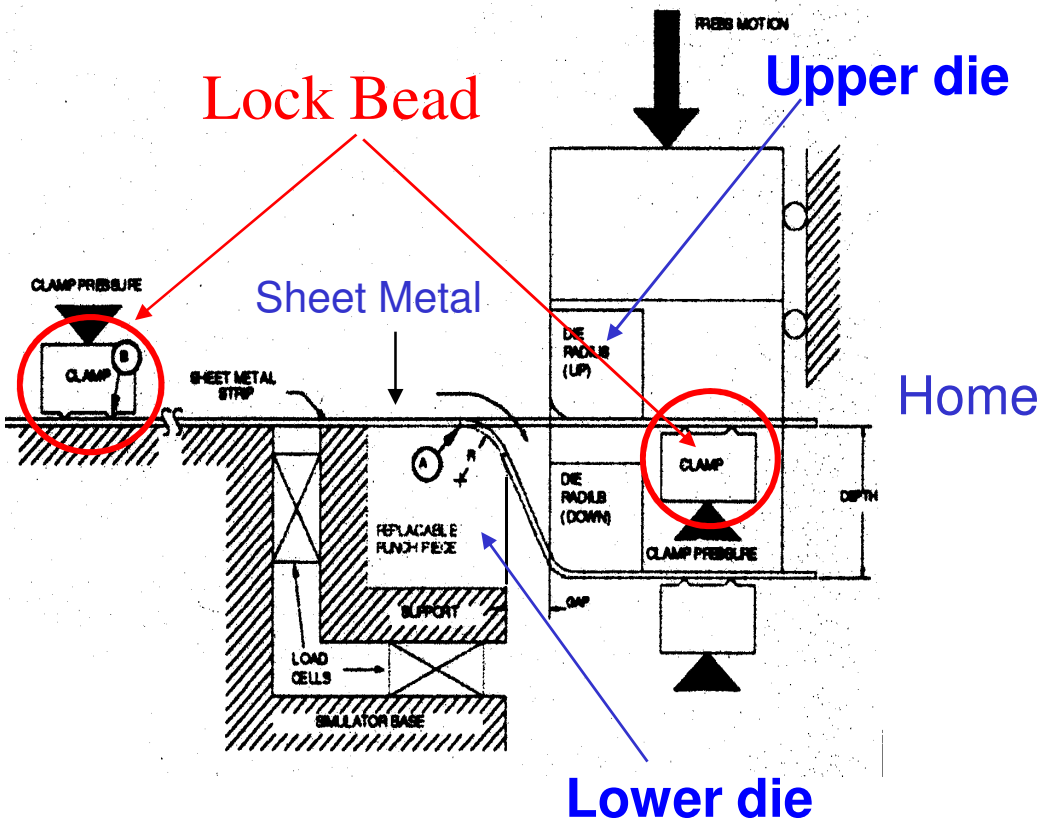
1st STAGE OF STAMPING -BINDER COSURE



1st STAGE OF STAMPING –BEGINNING OF DIE CLOSURE

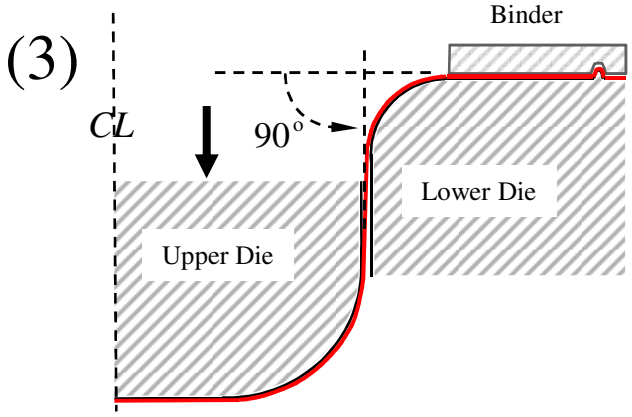


Stretch Forming Simulator (SFS)Test

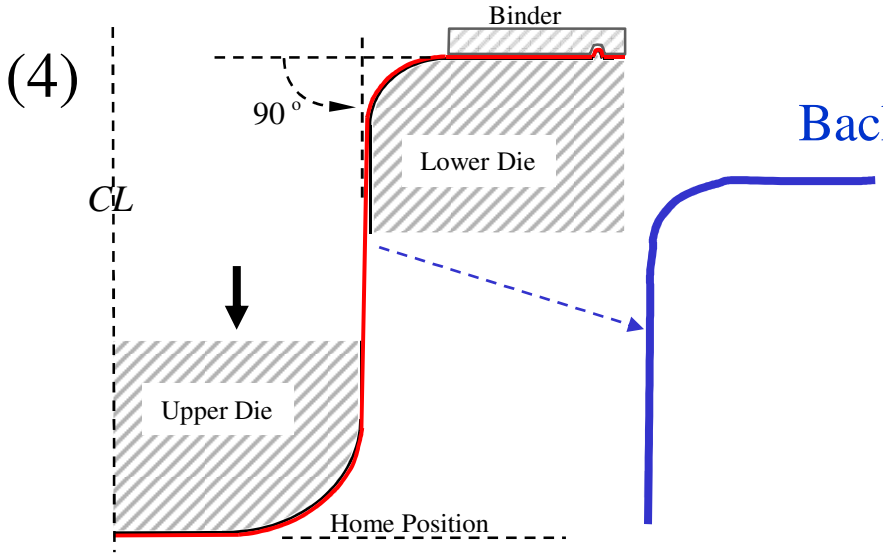


Shear Fracture In Stamping and Lab Simulative Test

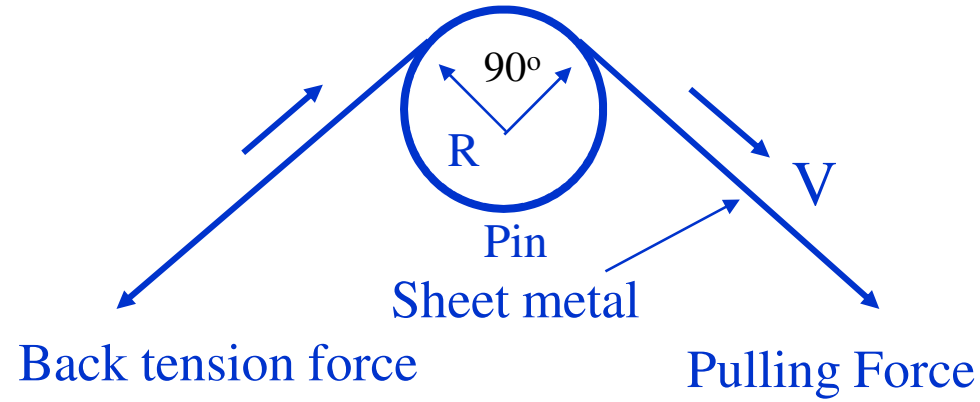
2ND STAGE OF STAMPING –INTERMEDIARY DIE CLOSURE



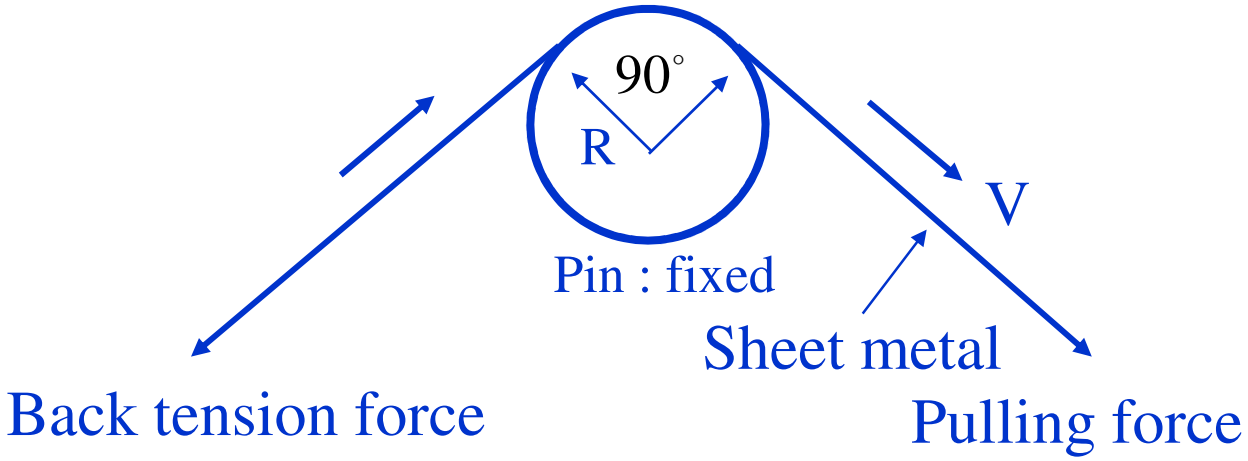
2ND STAGE OF STAMPING –DRAW HOME



Bend Under Tension (BUT) Test

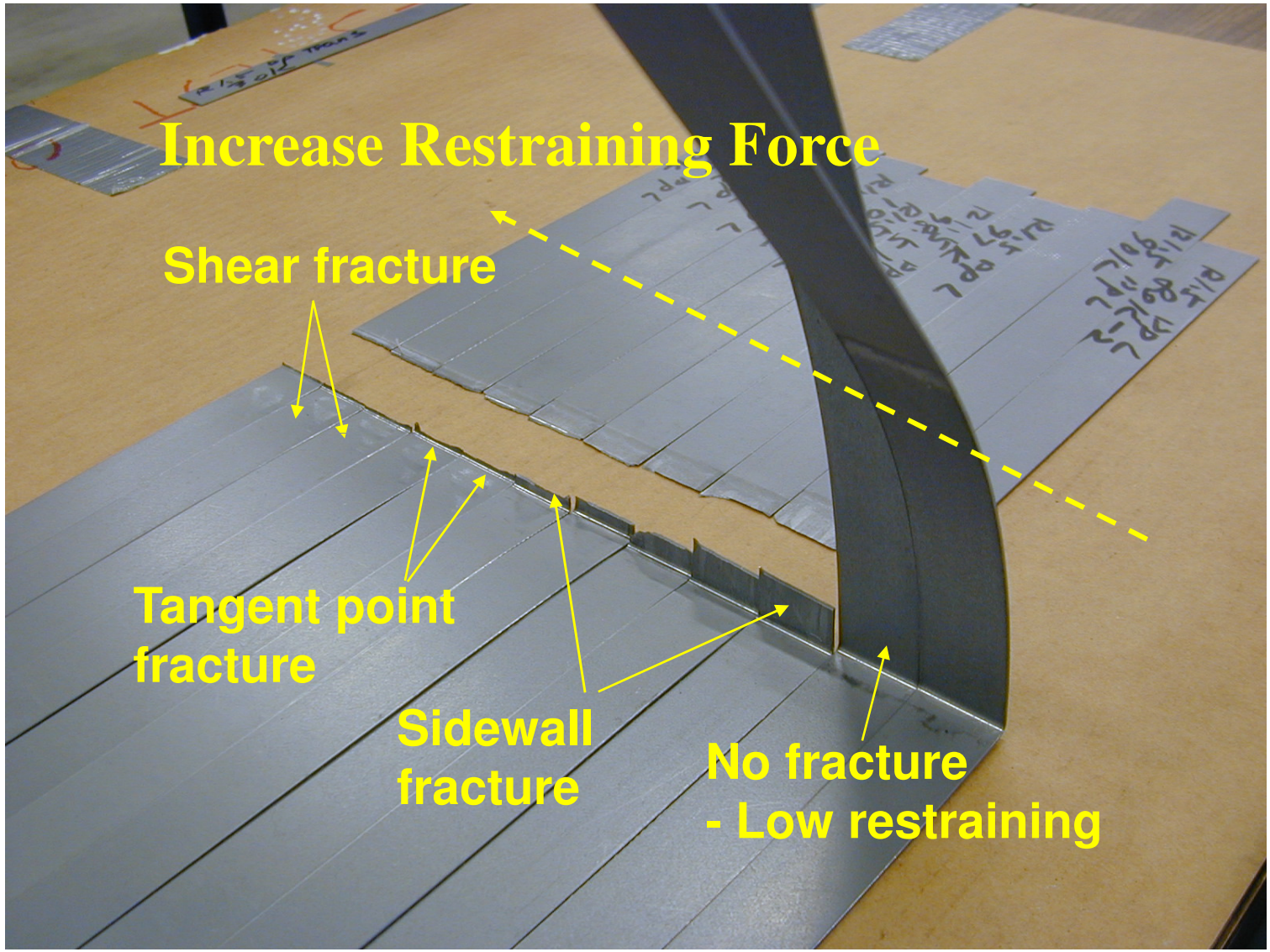


Bending Under Tension (BUT) Test

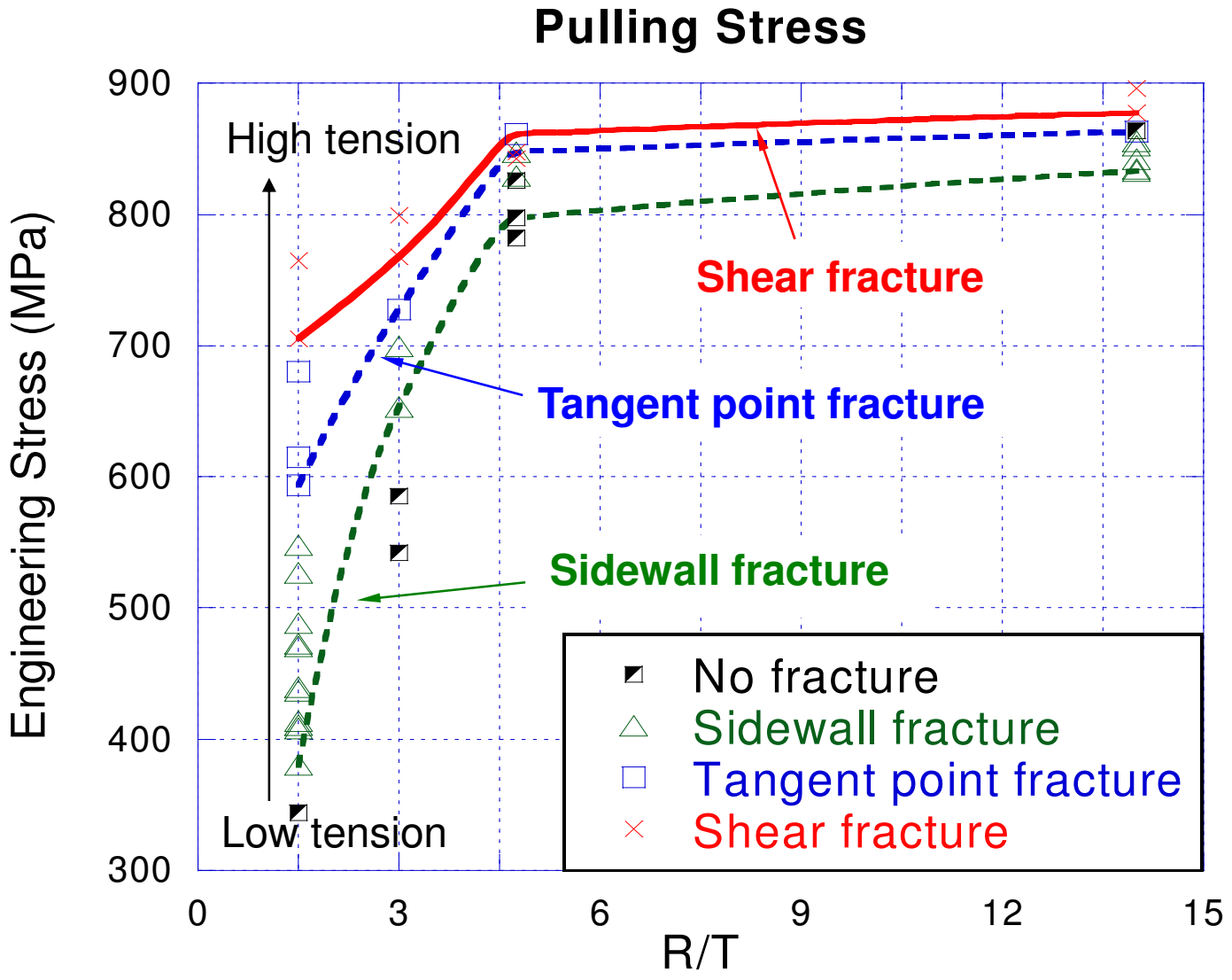


- Variation of back tension force
- Varies R/T (R= 1.5, 3, 5 and 14 mm)
- Fixed sliding speed
- Lubrication: Thin Teflon film

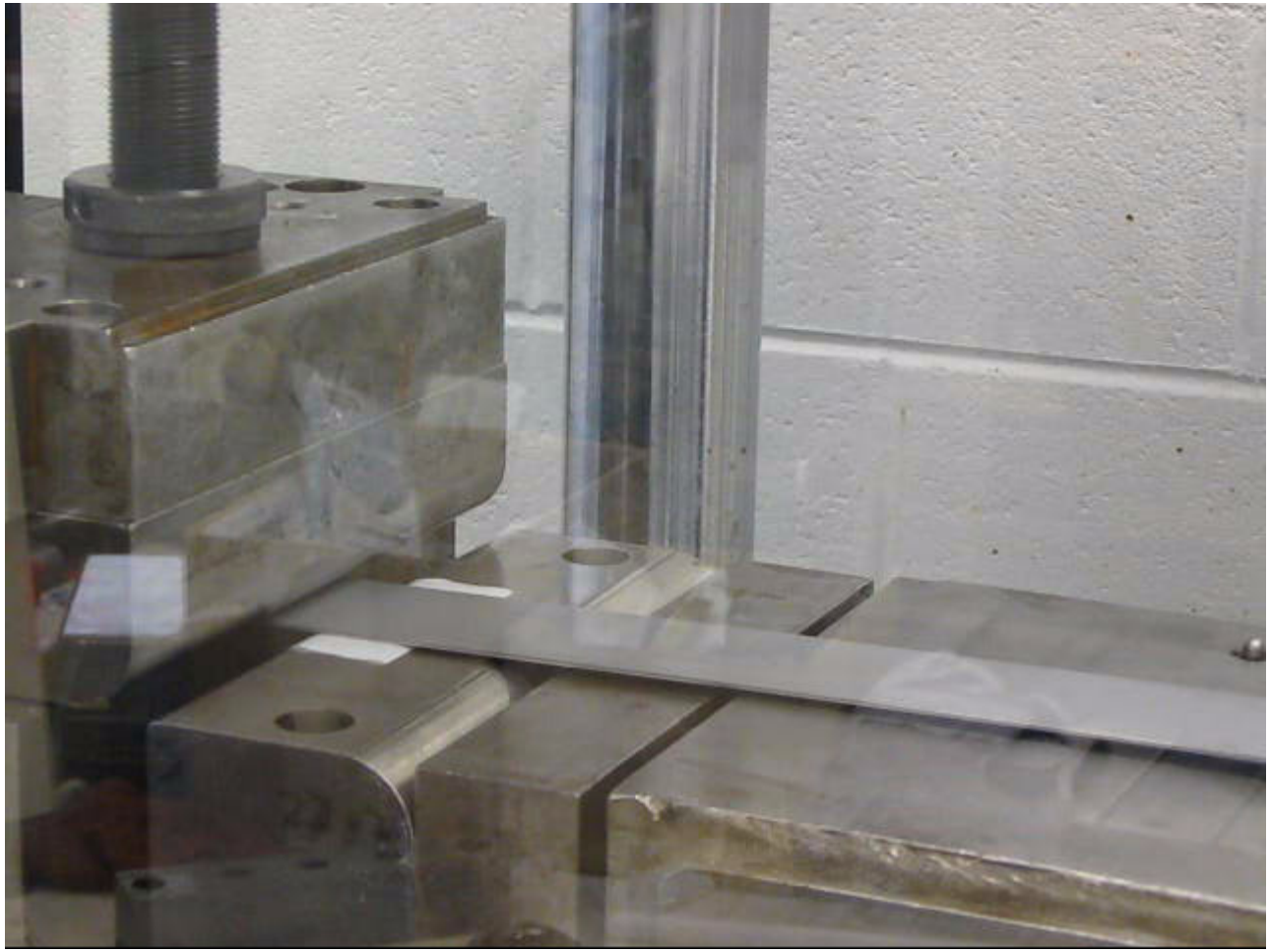
BUT Test Samples



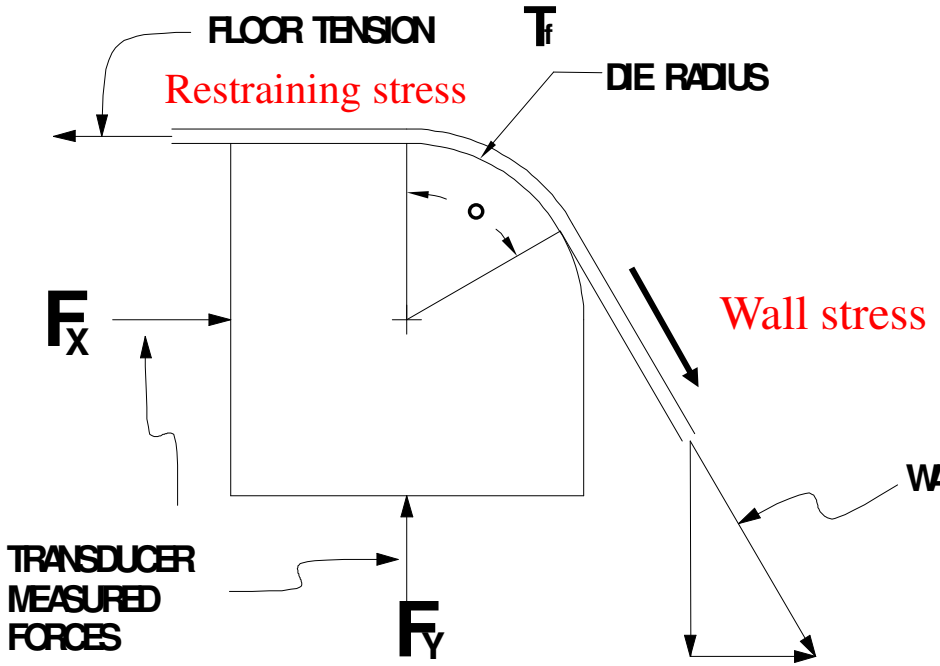
BUT Test Results



Stretch Forming Simulator (SFS) Test



Stress Calculations for SFS



$$0 = F_x - T_f + T_w * \cos(\phi)$$

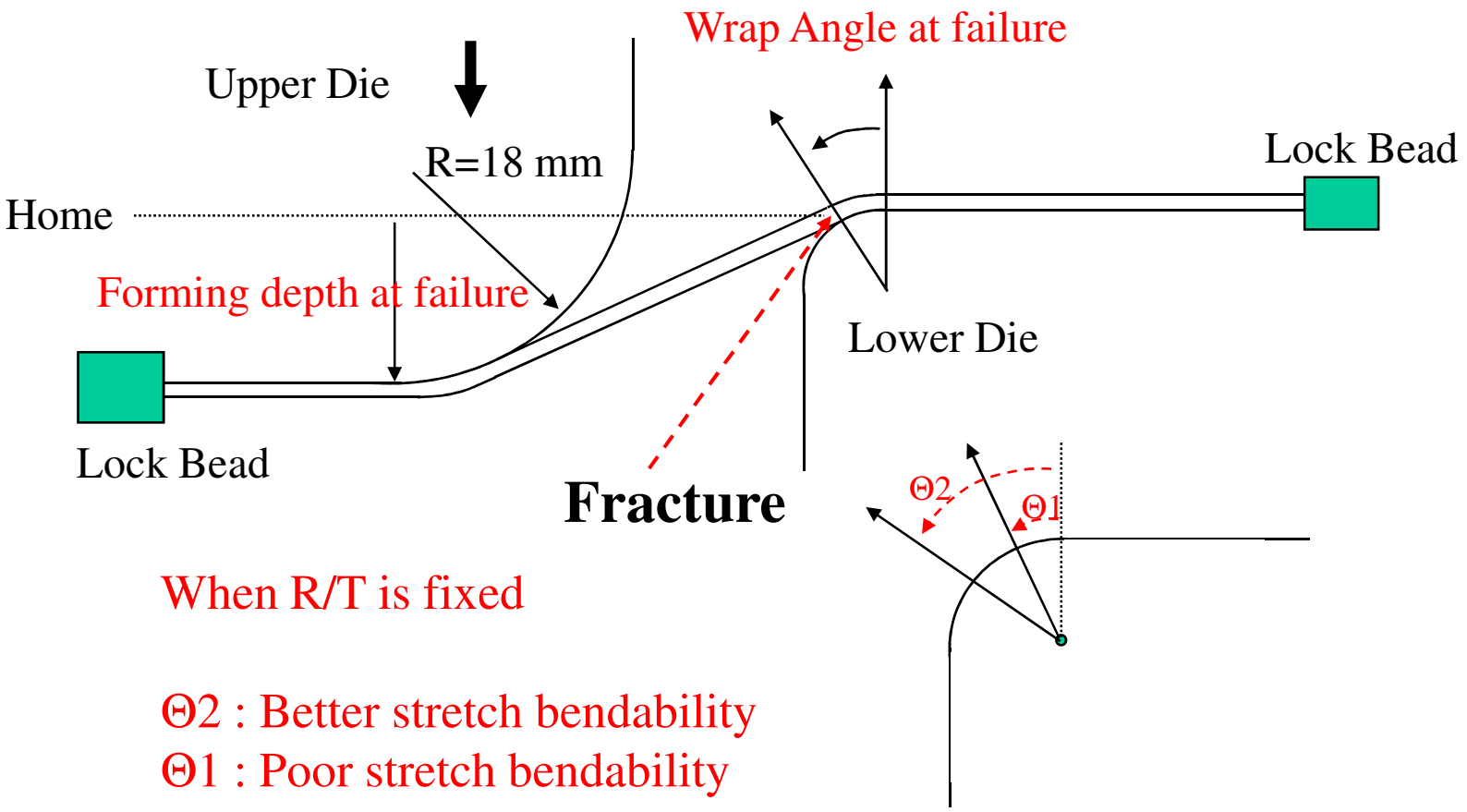
$$0 = F_y - T_w * \sin(\phi)$$

$$\Rightarrow T_w = \frac{F_y}{\sin(\phi)}$$ **(Wall tension)**

$$T_f = F_x + T_w * \cos(\phi)$$

(Floor tension, restraining)

Wrap Angle & Forming Depth at Failure



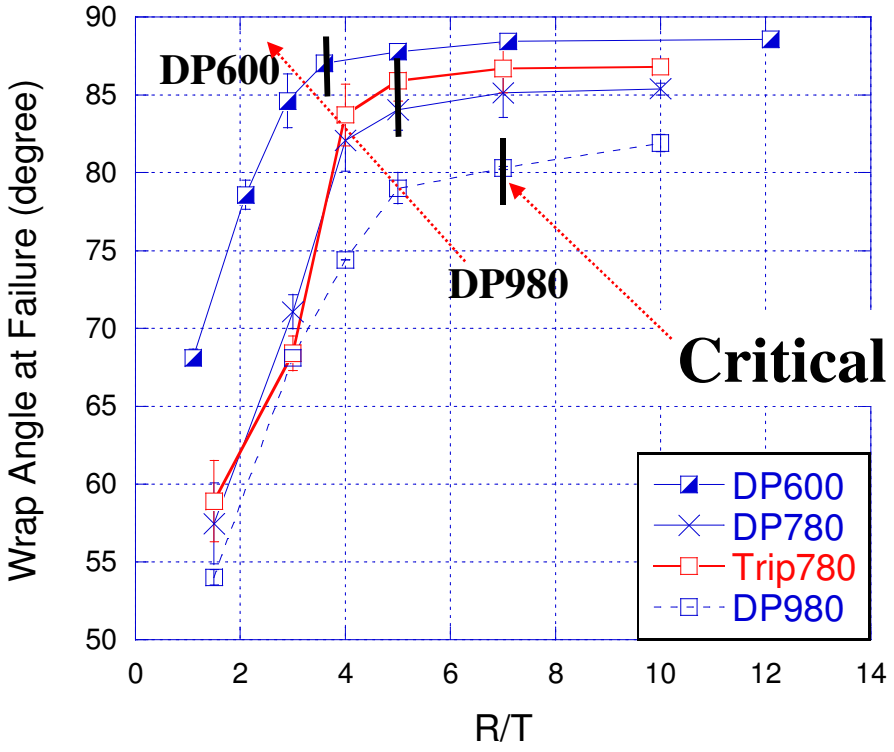
When R/T is fixed

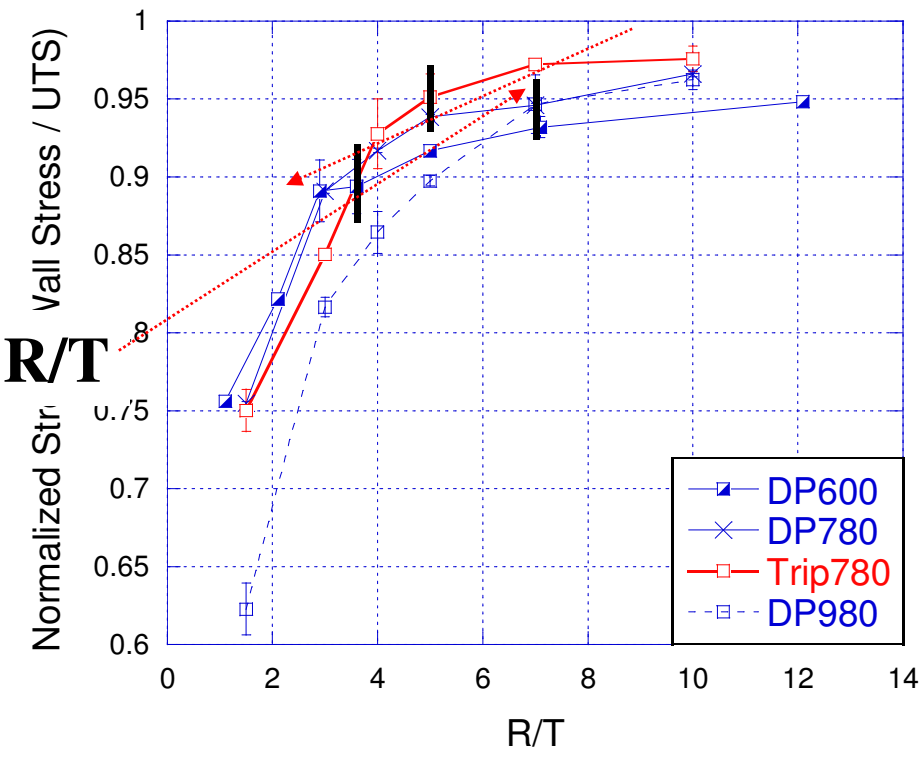
Θ2 : Better stretch bendability

Θ1 : Poor stretch bendability

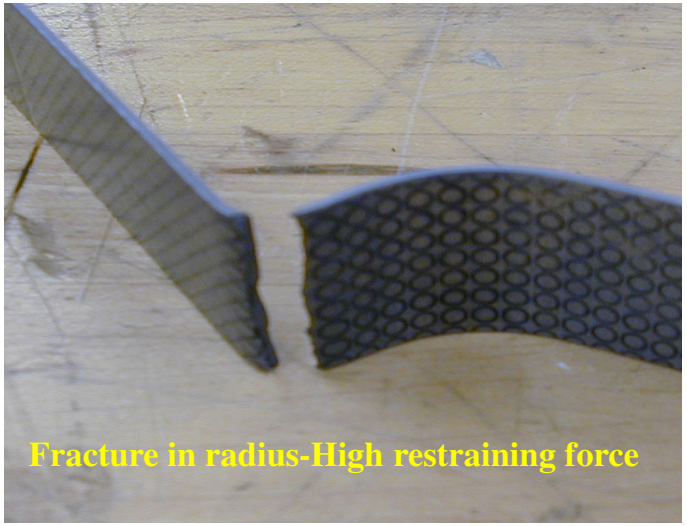
SFS Test Results

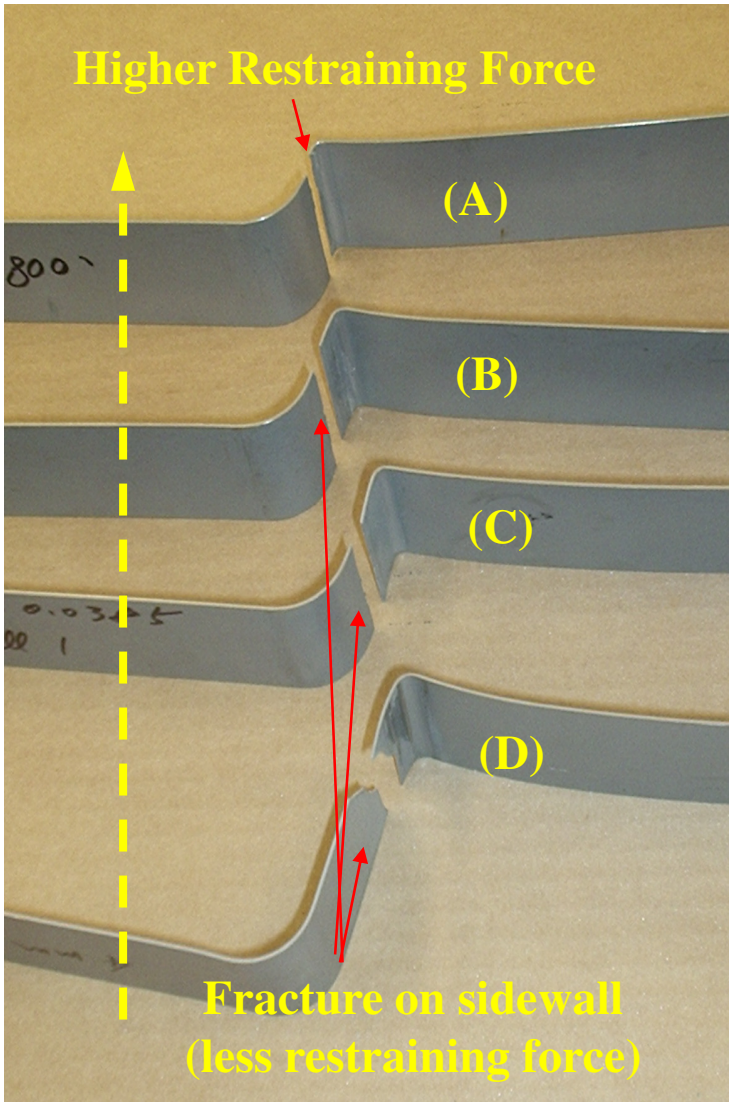
Smaller R/T for DP600



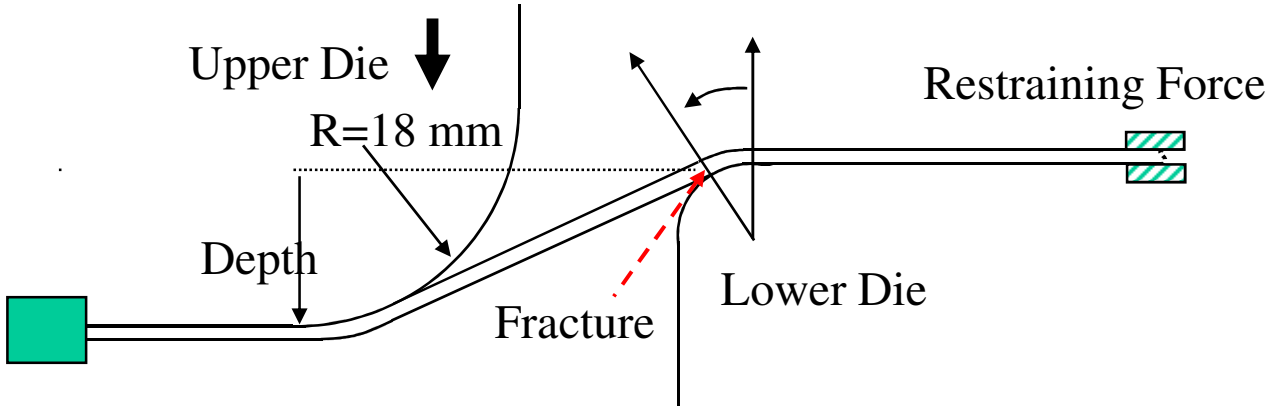


SFS Test - Effects of Restraining Forces

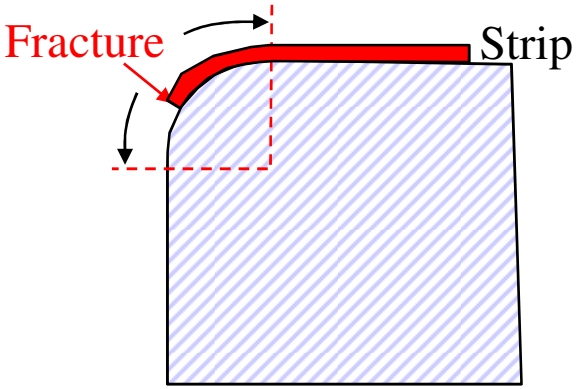




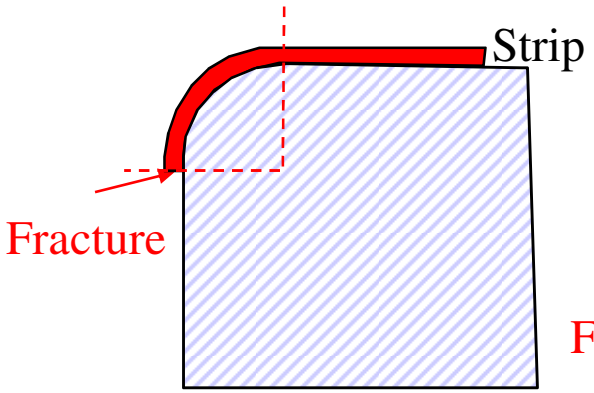
Failure Locations



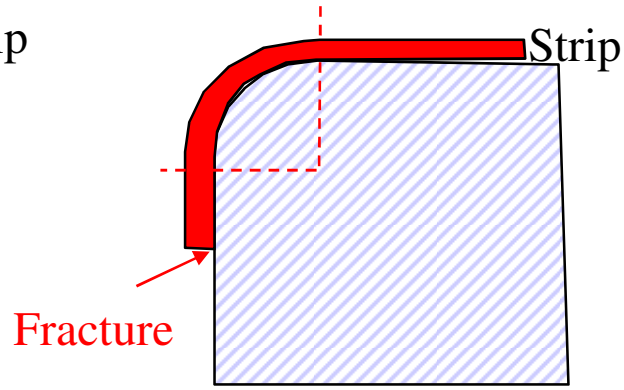
(1) Fracture within radius
- **Shear fracture**



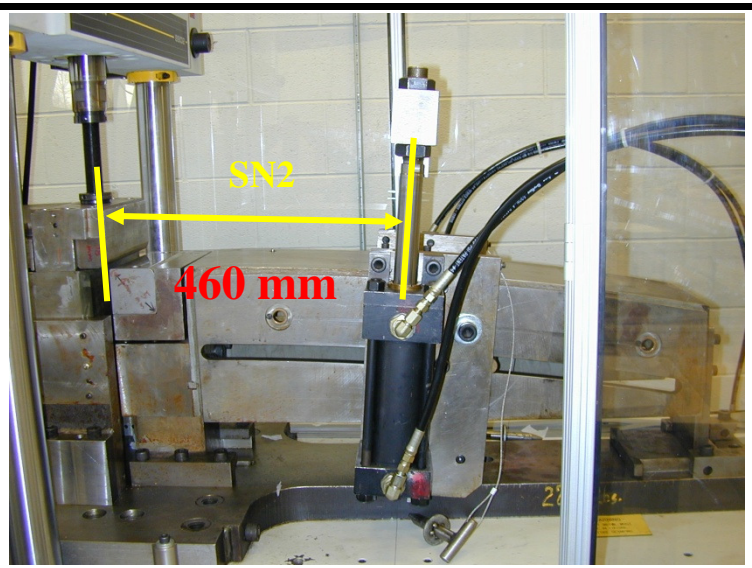
(2) Fracture at the tangent
- **Necking mixed failure**

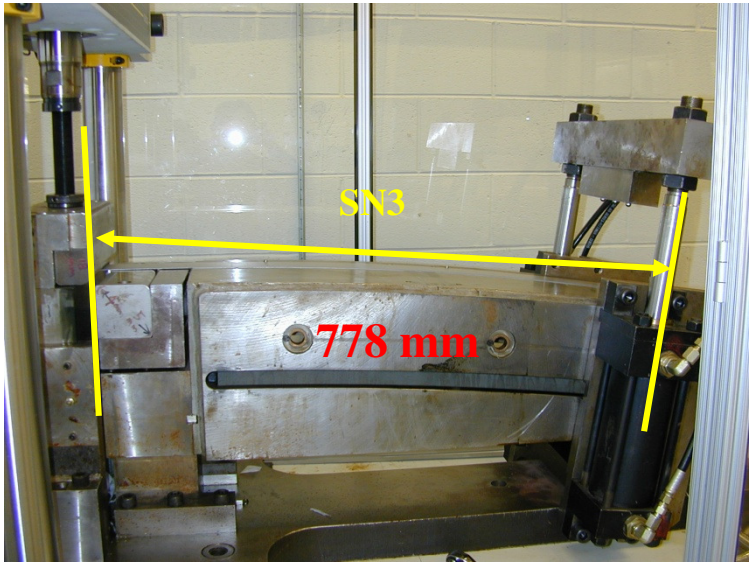


(3) Fracture on sidewall
- **Tensile type failure**



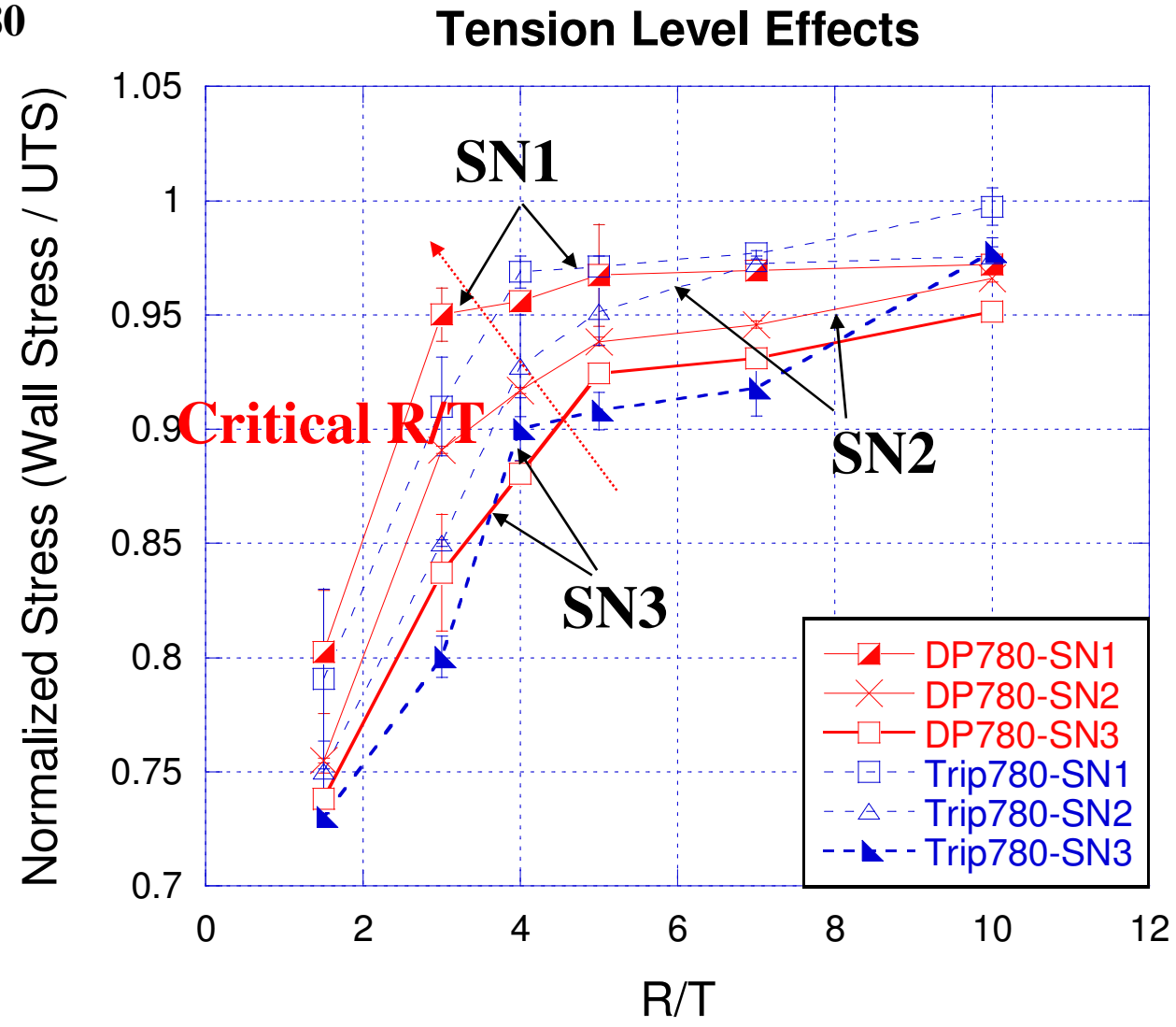
SFS Test - Effects of Tension Level



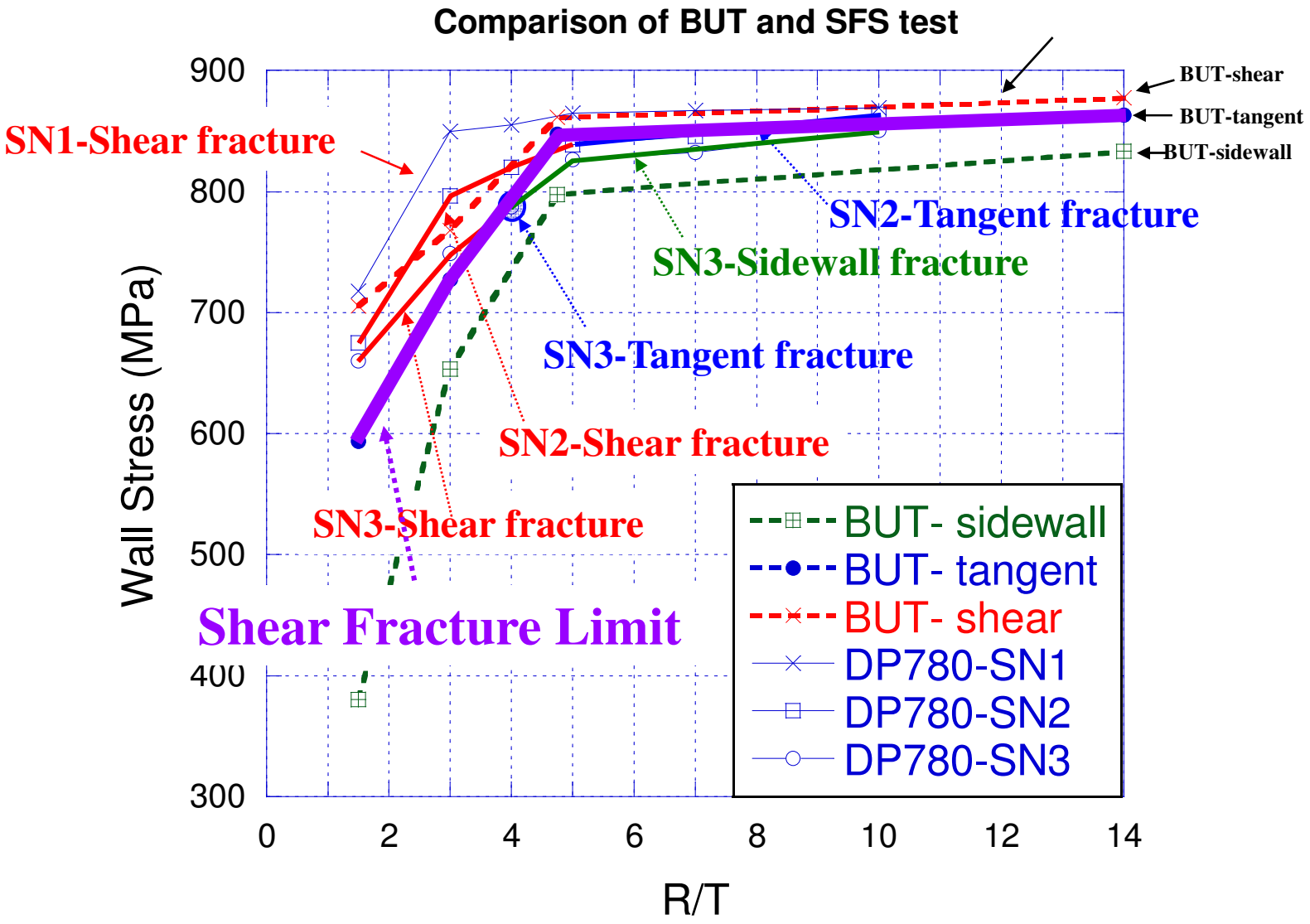


SFS Test - Effects of Tension Level

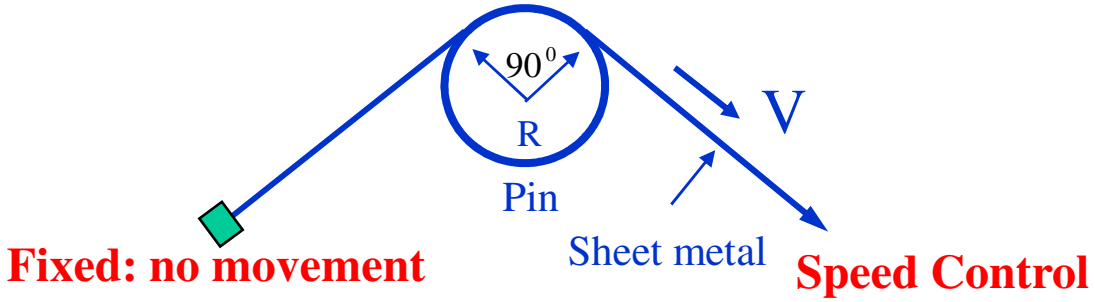
DP780, TRIP780
Transverse
1 mm



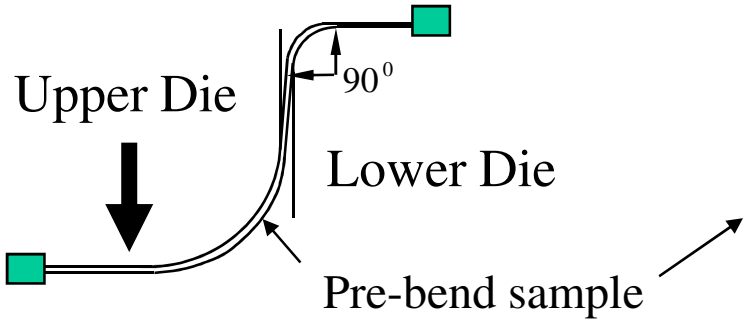
Fracture failure criterion

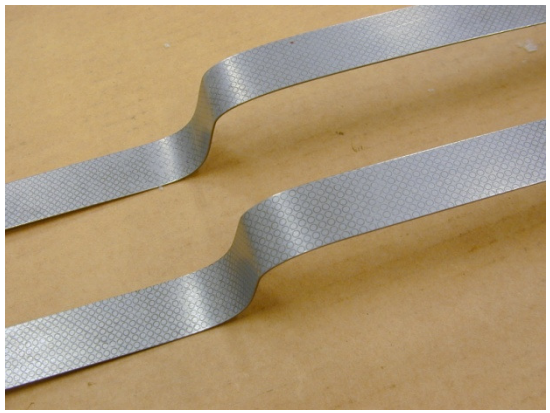


BUT-Stretch Forming Test (BUT-SF)

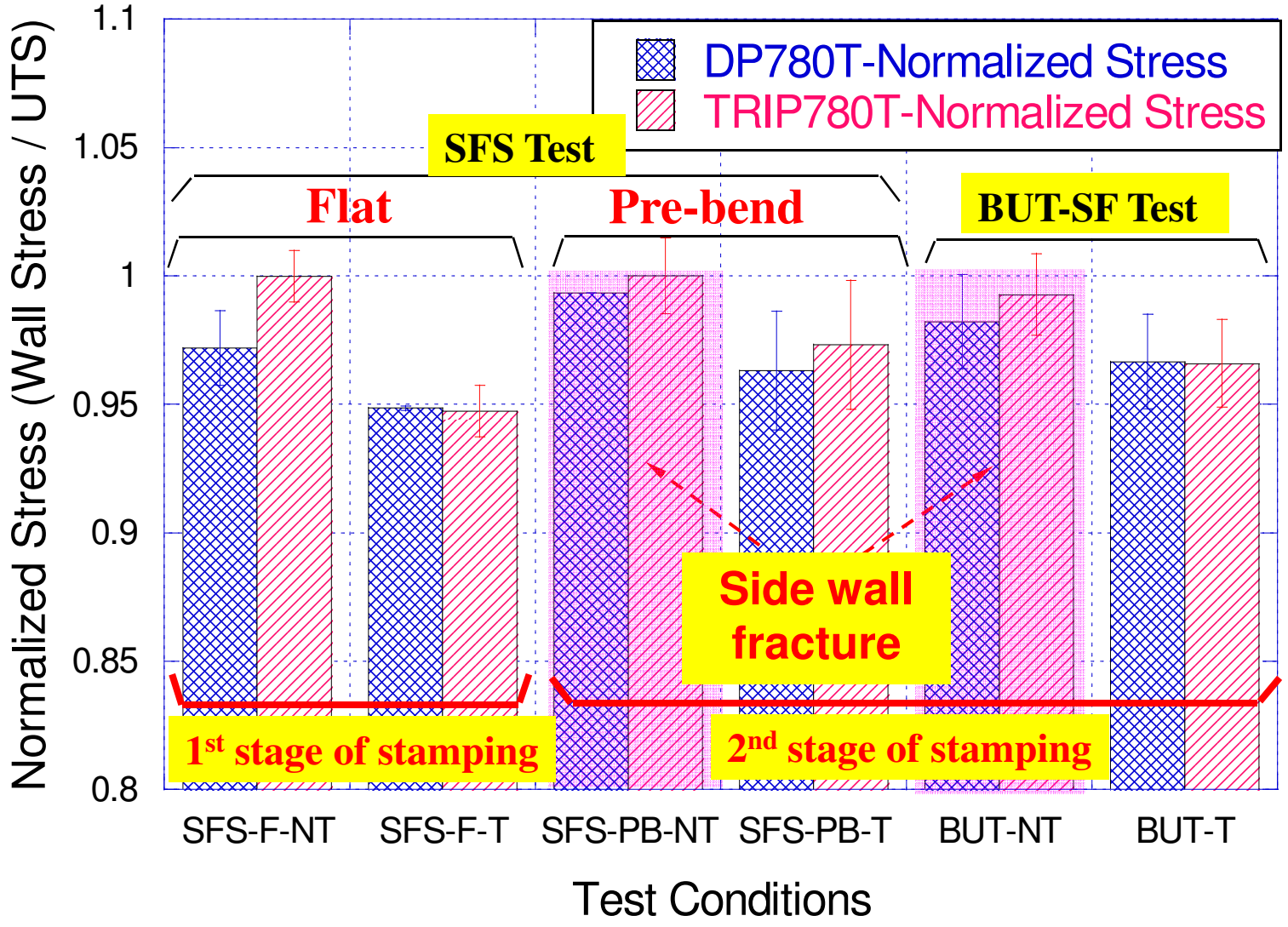


SFS Test on Pre-bend sample

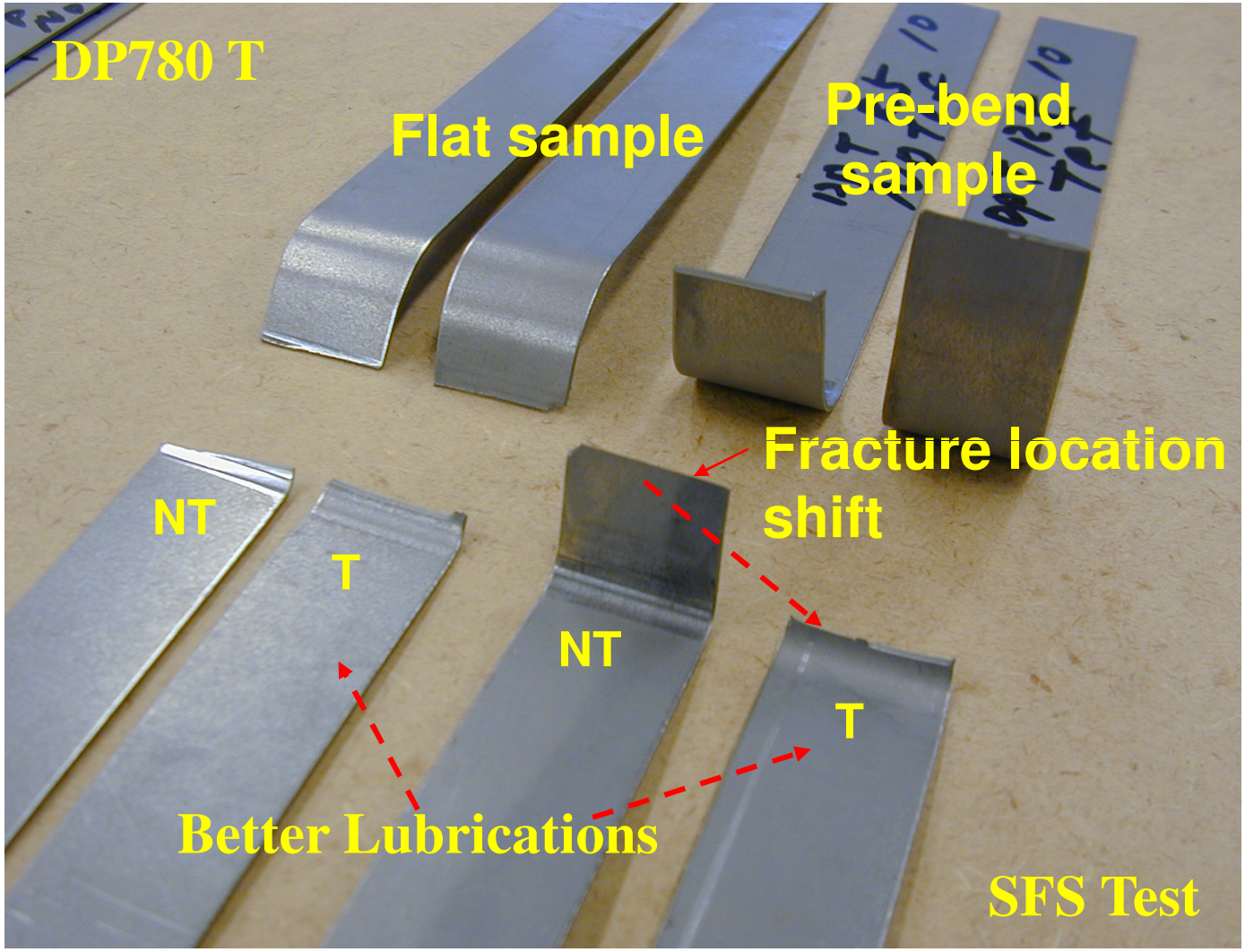




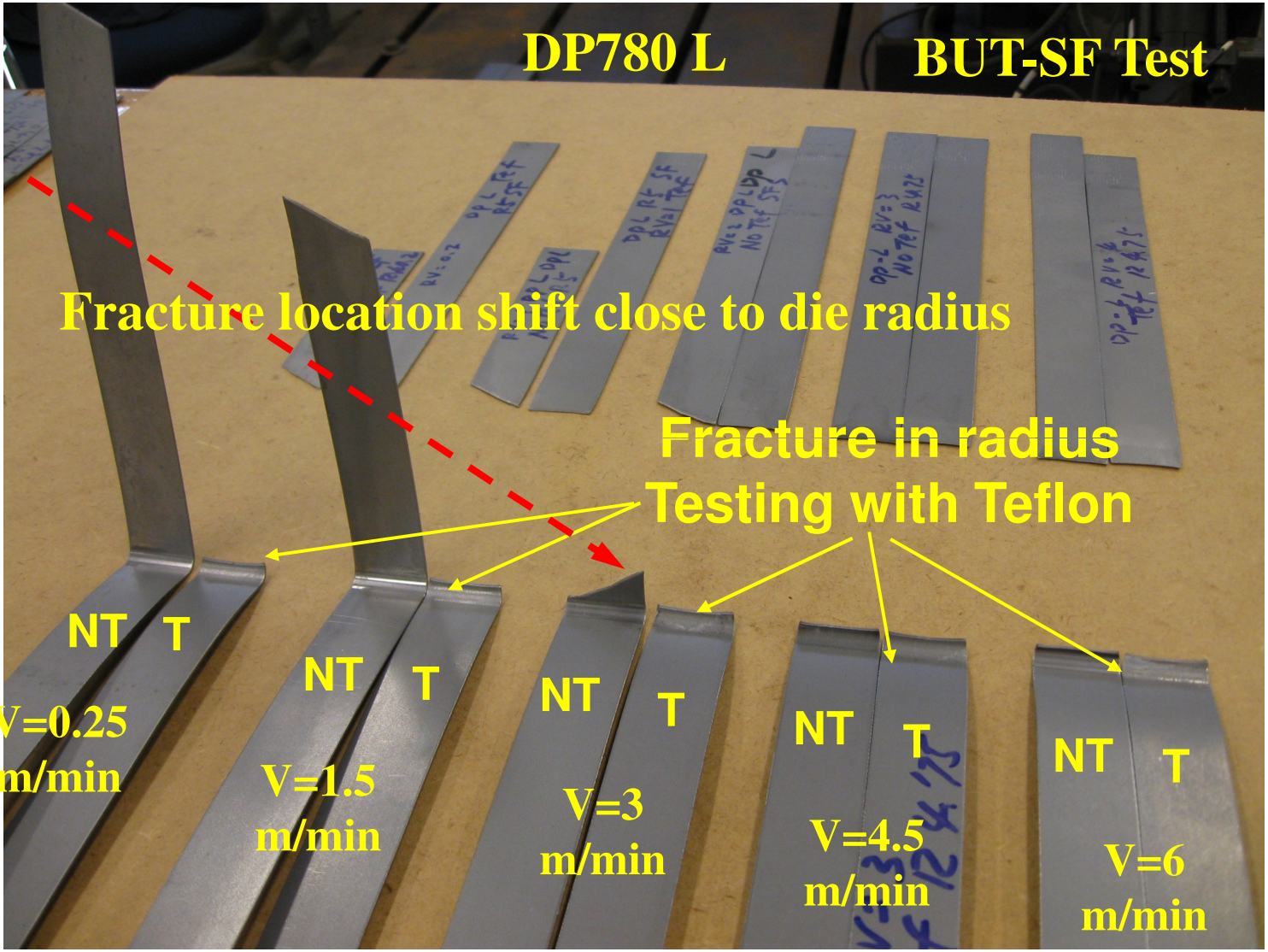
Different fracture locations
- Lubrication Effects



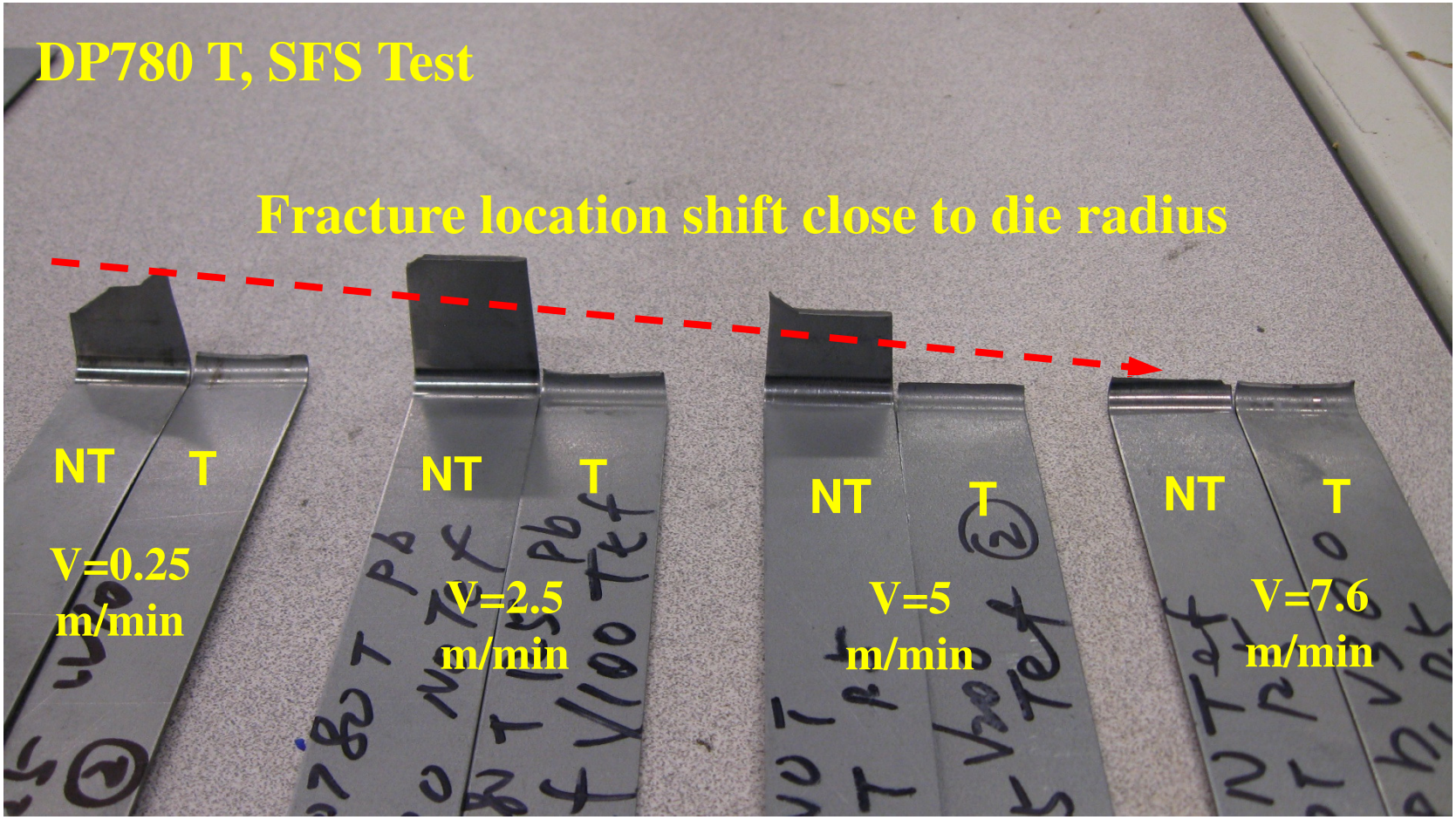
Different fracture locations
- Lubrication Effects



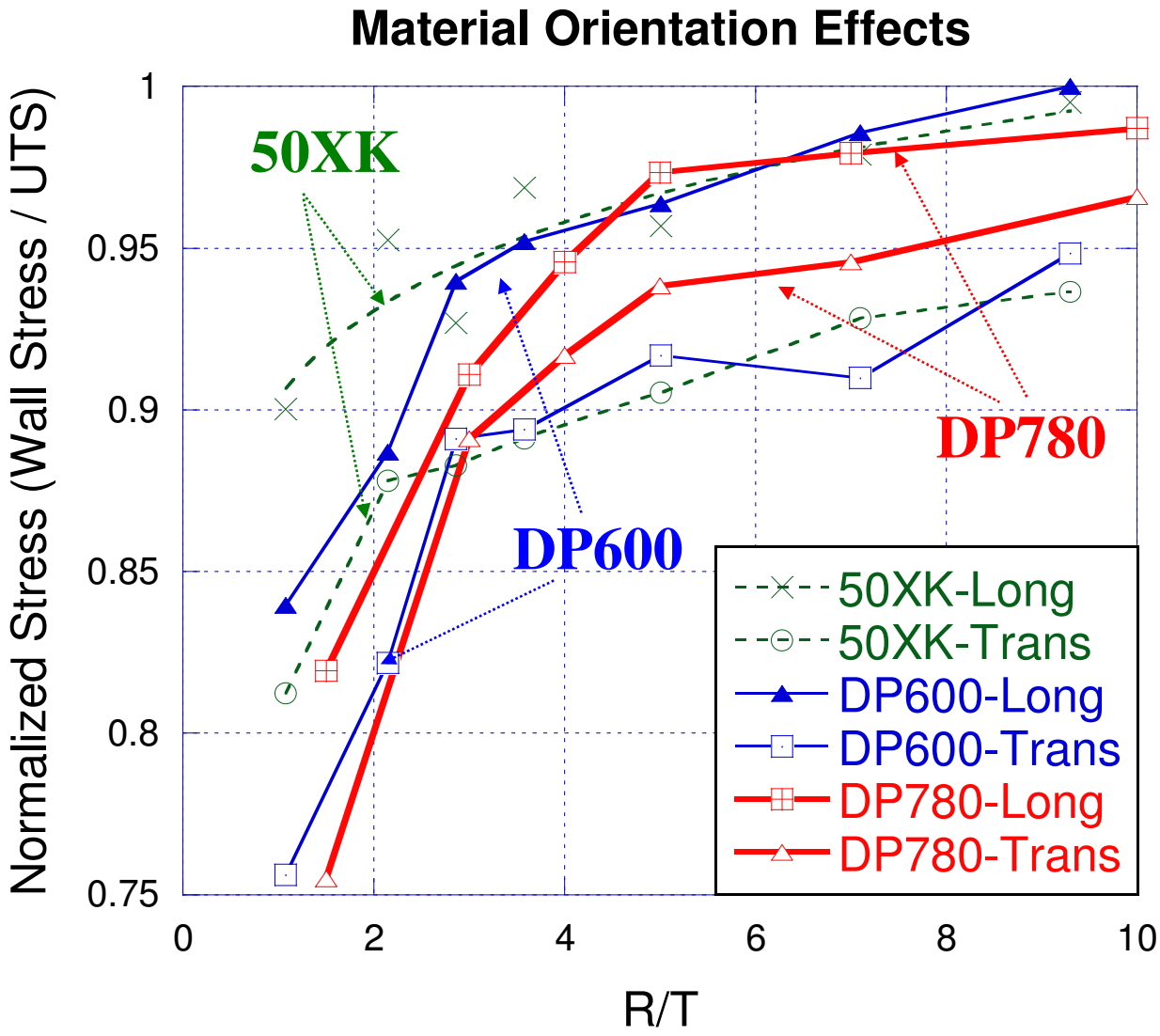
Different fracture locations
- Forming Speeds Effects



Different fracture locations
- Forming Speeds Effects



Material Orientation Effects



Summary

- Shear fracture was re-created using Stretch Forming Simulator (SFS) test and the Bending Under Tension (BUT) test with various radius to thickness (R/T) ratios for DP600, DP780, DP980 and TRIP 780.
- Shear fracture depends not only on the R/T ratio but also on the tension level applied during bending.
- The higher grade AHSS tends to have a shear fracture transition zone at a higher R/T.
- Three types of specimen failures were observed: failure in radius (shear fracture), failure in the boundary or tangent point between the radius (necking mixed shear fracture) and the failure in the side wall (tensile failure). The transition from shear fracture to tensile type failure is very sensitive to the restraining condition or the tension level applied during the bending.

Summary

- The fracture limit curves of SFS test correlate very well with BUT test results. The tangent point fracture limit curve from BUT test should be considered as the shear fracture limit. This is recommended for use as the shear fracture failure criterion for computer simulations.
- Forming speeds and lubrication conditions are found to have effects on fracture locations and the fracture timing in the stamping. The higher speed and better lubrication tends to cause fracture on material close to die radius.
- Material orientations are found to have effects on fracture limit for the test materials. The longitudinal direction has a slightly higher fracture limit than the transverse direction of the test AHSS.

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