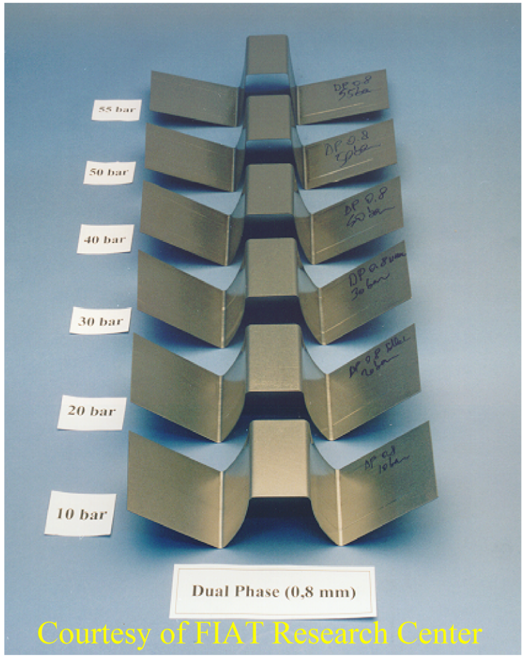
A STUDY OF SPRINGBACK USING RADIOSS INCREMENTAL

- What is springback ?
- Relevant material properties
- Mechanics of the bending/unbending
- Test case description
- Model description
- Results

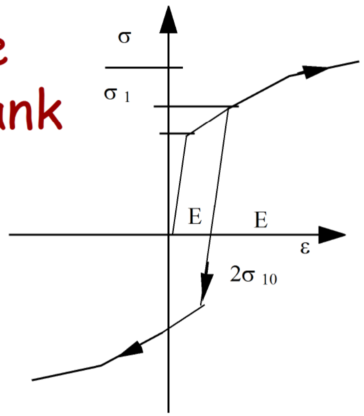
SPRINGBACK

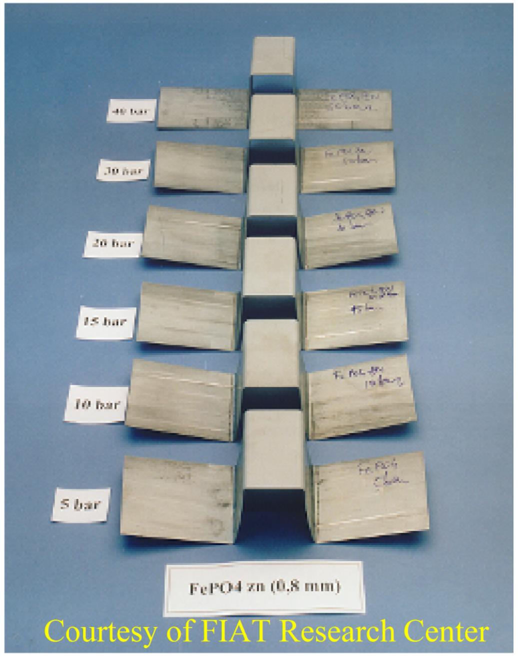


The plastic deformation of the blank is induced by the action of tool forces

To balance these forces, stresses are generated in the blank

When the tools are taken away, the blank deforms a little to reach a different equilibrium point

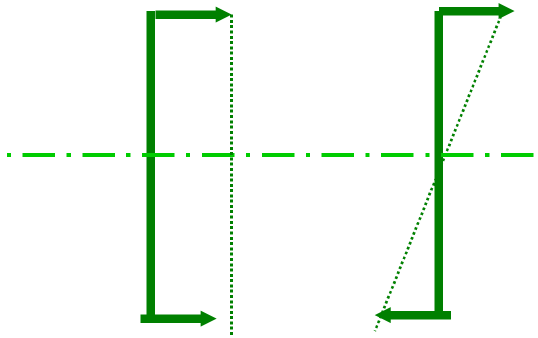




SPRINGBACK MECHANICS

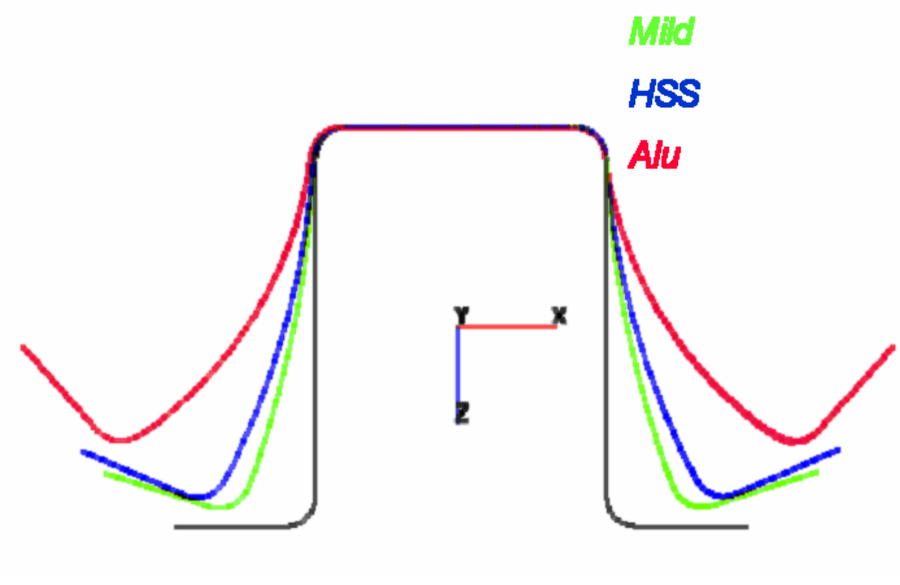
The most important thing about springback is that flexure deformation gives important springback, but membrane does not

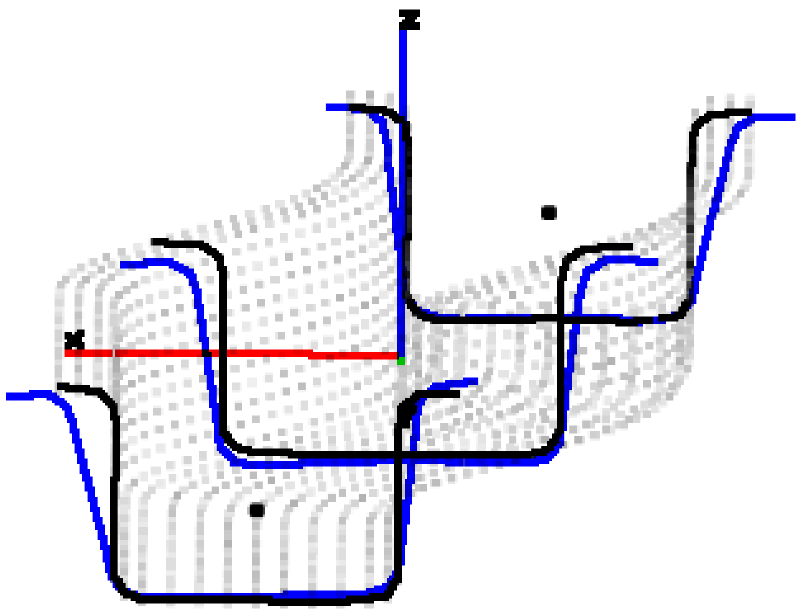
The rest is about finding where the flexure comes from …



$$\varepsilon = \varepsilon_m + \varepsilon_f$$

$$\varepsilon_f \approx \frac{z}{R}$$





MATERIAL PROPERTIES RELEVANT TO METAL FORMING

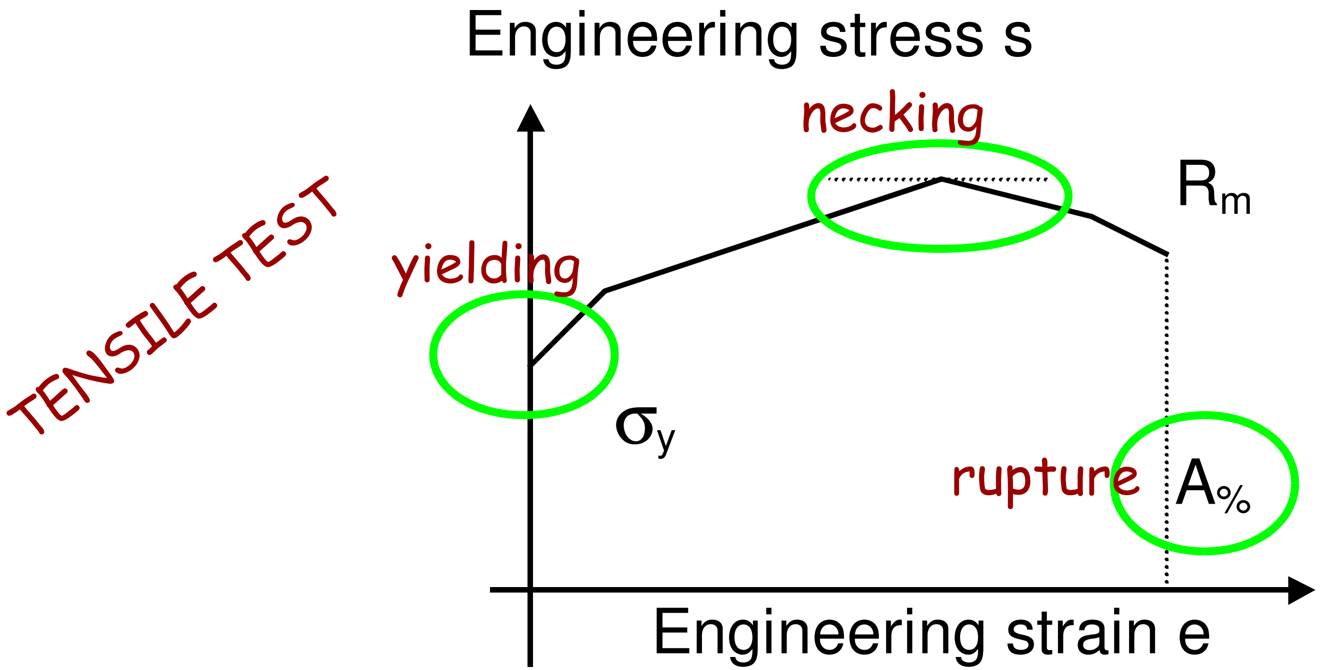
- Ductility – strain hardening (behavior under monotonic loading)
- Hardening type (behavior under cyclic loading)
- Anisotropy
  - Transverse
  - Planar
- Strain rate sensitivity
- Friction

DUCTILITY

A basic engineering notion is that material behavior in the first stages of deformation is approximately elastic, i.e. the material returns to its initial state after the external cause (force) is removed.

Further deformation will be at least partially permanent. For metals, this pattern of permanent deformation is called plasticity.

After the onset of plastic deformation (yield point) the stress generated in the material continues to grow (even though at a slower pace) as deformation increases. This phenomenon is called ***strain hardening***. The ability of the material to deform plastically before failure is called ***ductility***.



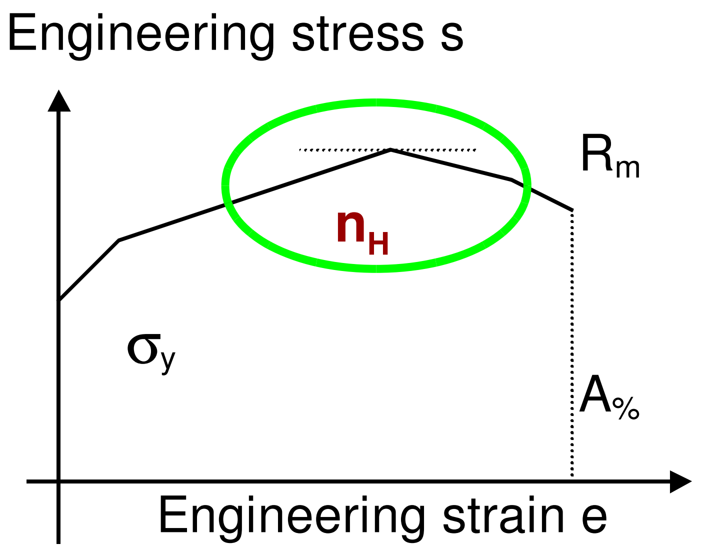
RADIOSS MATERIAL LAWS

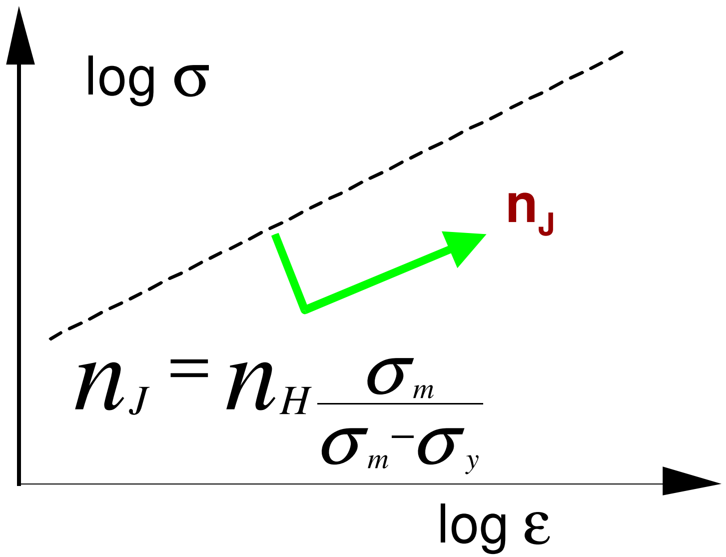
Hill / Krupkovsky-Swift
(also available for one-step)

$$\sigma = K\left(\varepsilon_p + \varepsilon_0\right)^{n_H}$$

Johnson-Cook

$$\sigma = \sigma_y + B\,\varepsilon_p^{n_J}$$



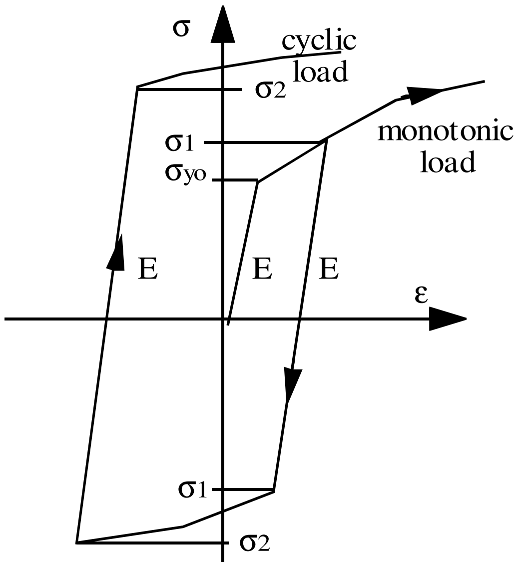


$$n_J = n_H \frac{\sigma_m}{\sigma_m - \sigma_y}$$

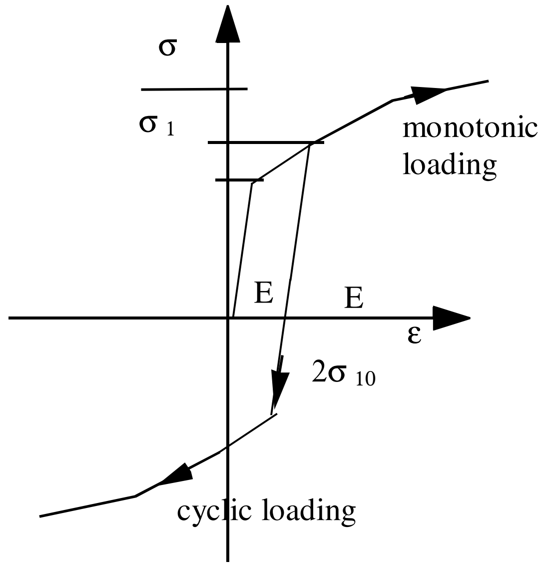
BEHAVIOR UNDER CYCLIC LOADS

Material resistance (yield and ultimate strength) may be significantly different after a prior deformation.
Two idealized models are used:

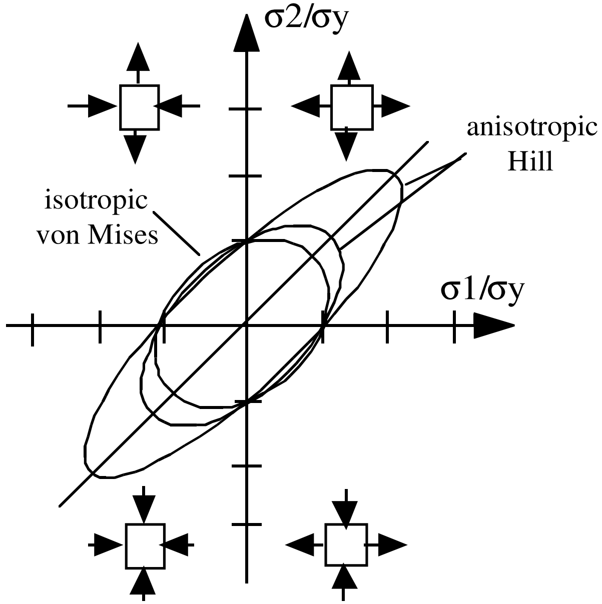
- Isotropic hardening. If loading is reversed after a first monotonic loading (up to σ_1), the second yielding point is symmetrical with respect to the maximum stress in monotonic loading ($-\sigma_1$).
- Kinematic hardening. If loading is reversed after a first monotonic loading (up to σ_1), the material shows always the same apparent resistance to yielding, so that the yielding point for the reverse load is $\sigma = \sigma_1 - 2\sigma_{y0}$



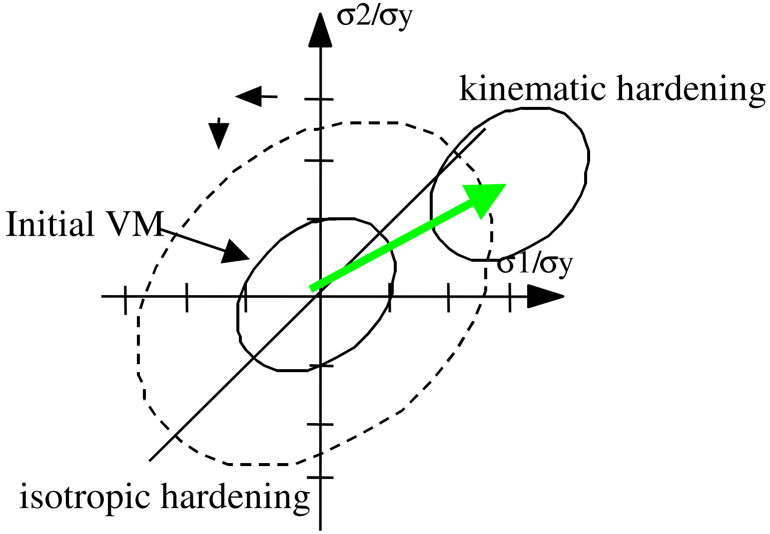
isotropic hardening



kinematic hardening



Anisotropy changes the shape of the initial yield surface

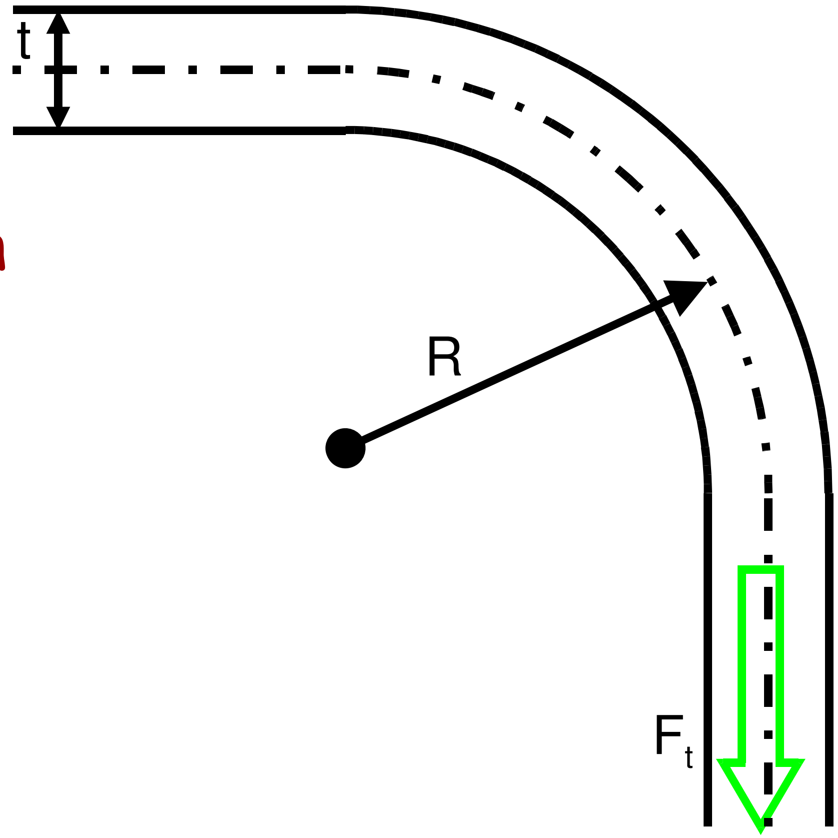


Hardening type change the shape of yield surface during loading

BENDING/UNBENDING MECHANICS

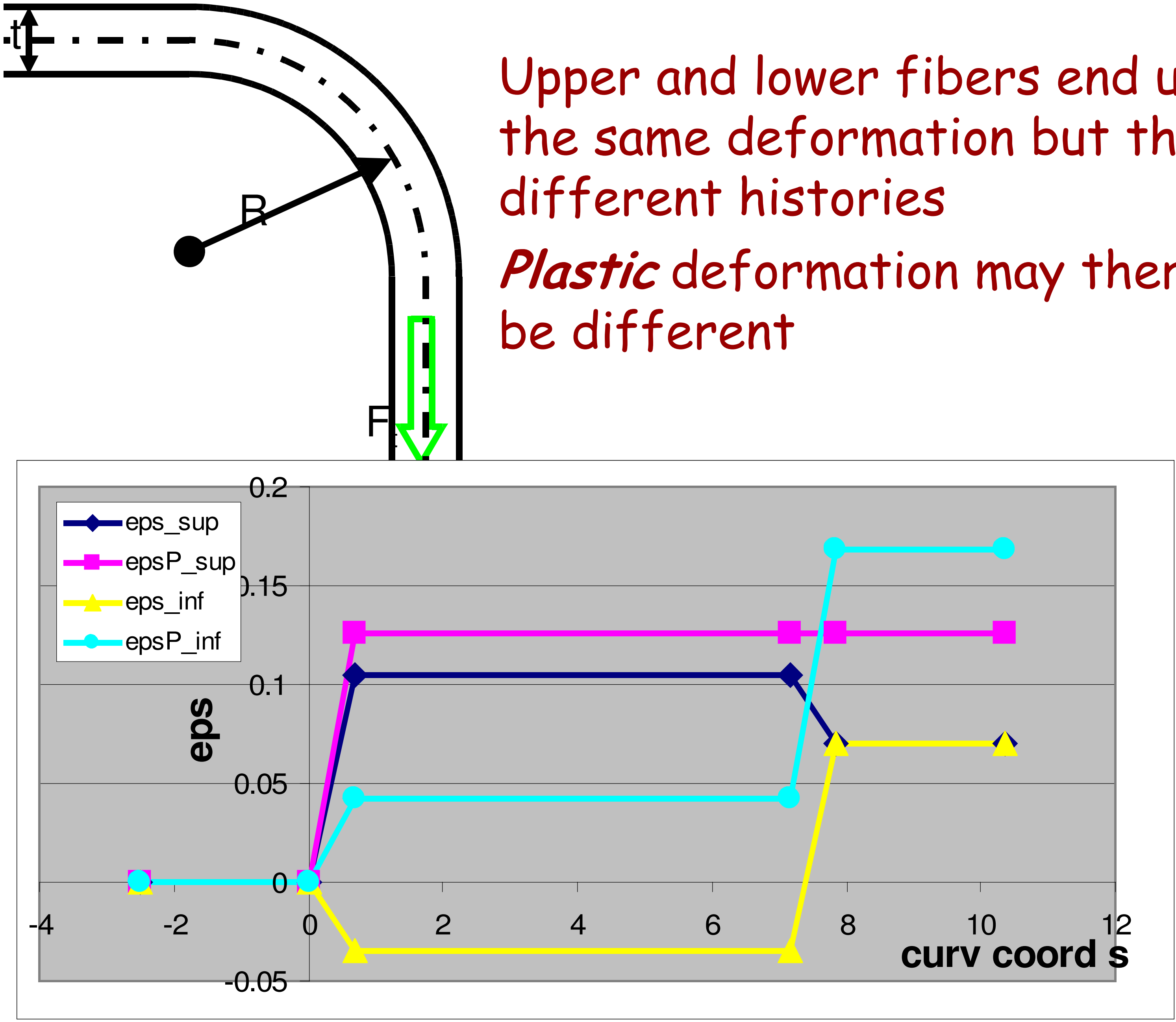
Bending/unbending:

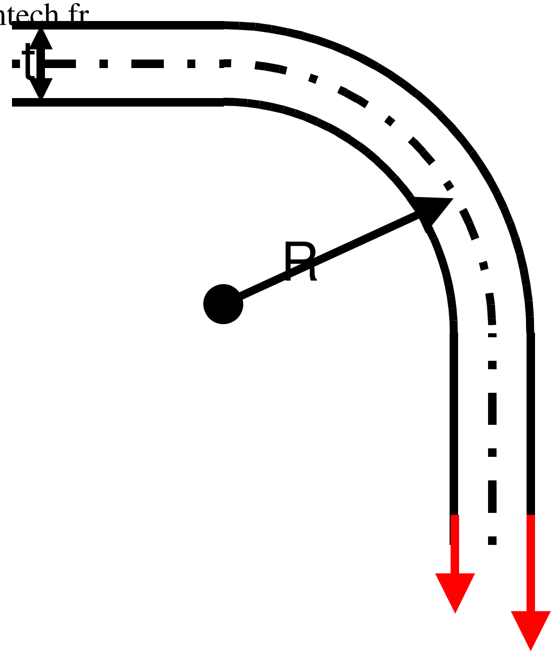
- Creates a membrane plastic deformation ε_M with traction forces F_t below yield level (beware of the models)
- Freezes a state of flexural stress which can be very complex depending on the hardening caracteristics



Upper and lower fibers end up with the same deformation but through different histories

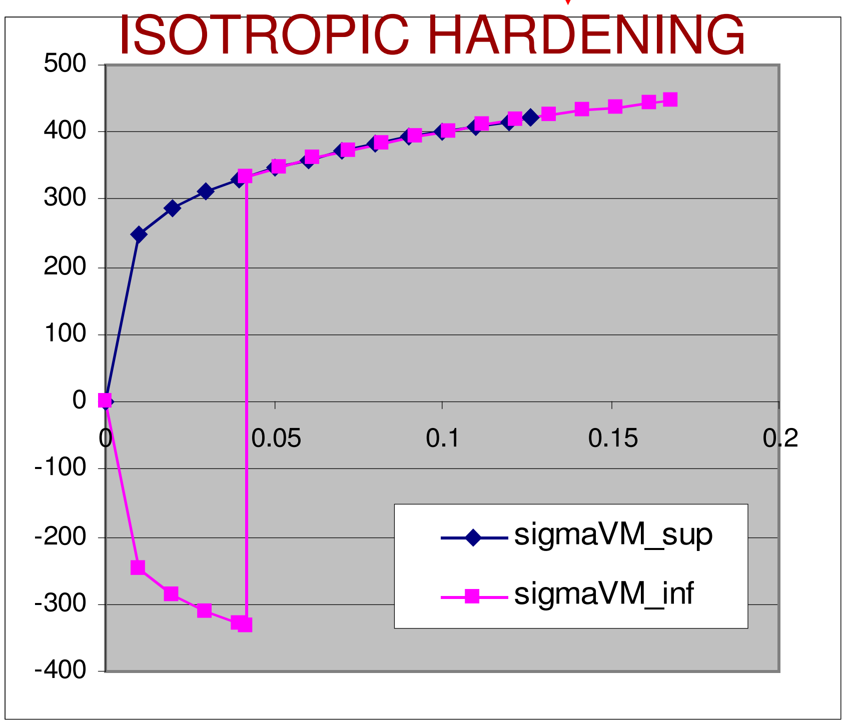
Plastic deformation may therefore be different

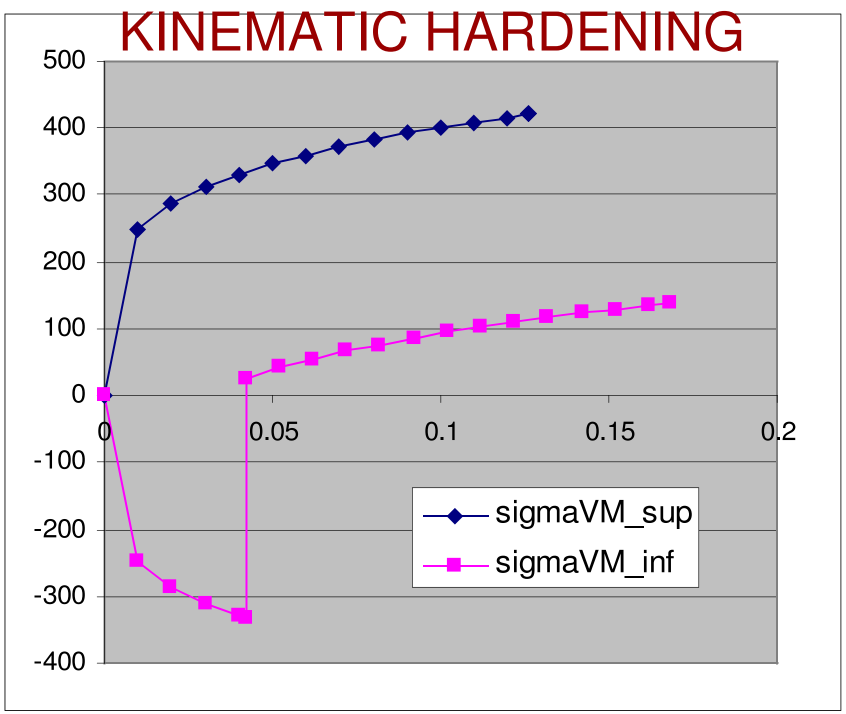




Different deformation cycles mean that the final stress is different

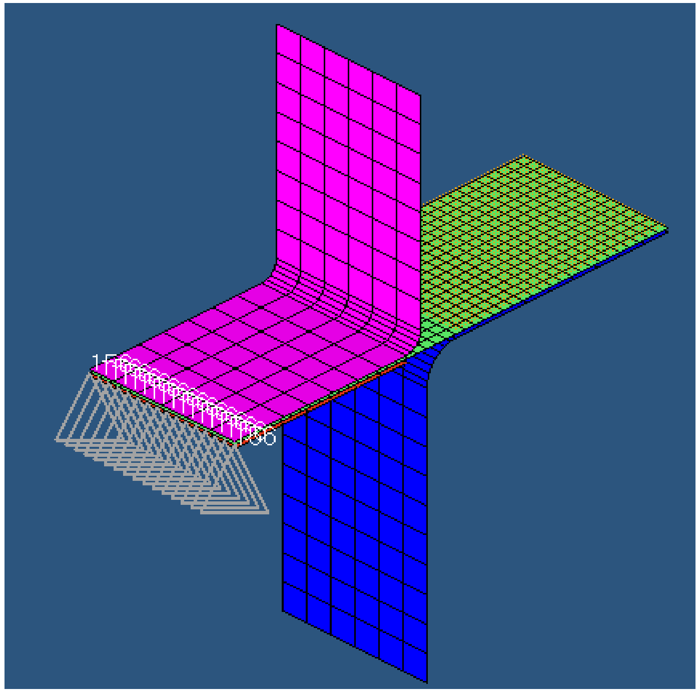
The section will spring back with a final curvature even if the shape after forming does not have any





FE MODEL

- 675 elements in blank (2 mm mesh)
- Punch (3 mm radius), speed control
- Bhl, counter punch, force control (parameter)
- Die, 6 mm radius, fixed

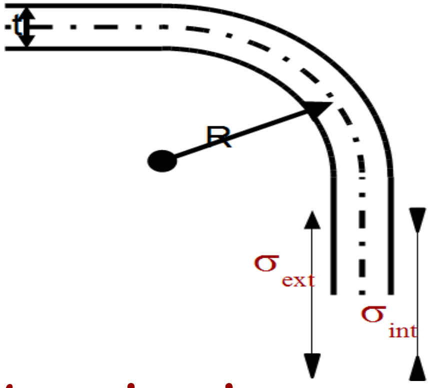


Design Of Experiment

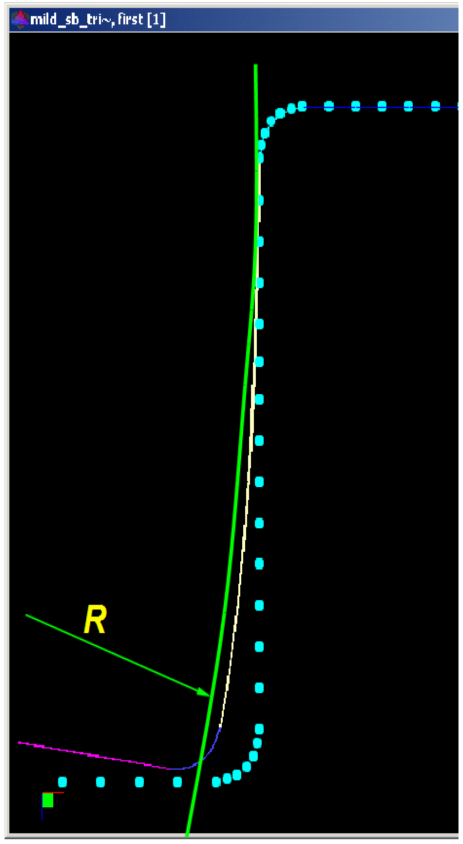
- Parameters
  - Krupkowsky hardening coefficient
    0.08 – 0.15
  - Kinematic hardening coefficient
    0 (purely isotropic) – 1 (purely kinematic)
  - BHL restraining stress 15 – 30 MPa

Design Of Experiment

- Responses
  - Residual stress on wall



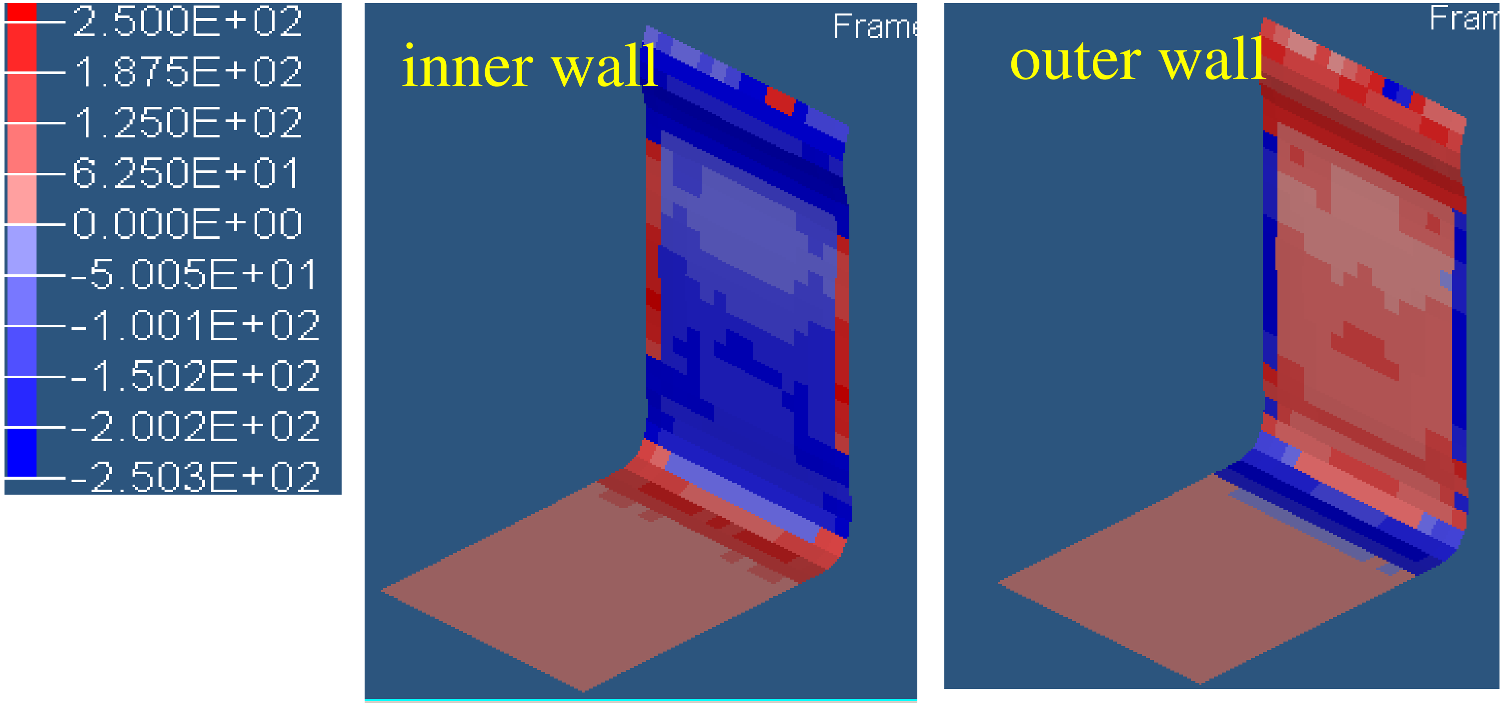
  - Springback shape (wall curvature)



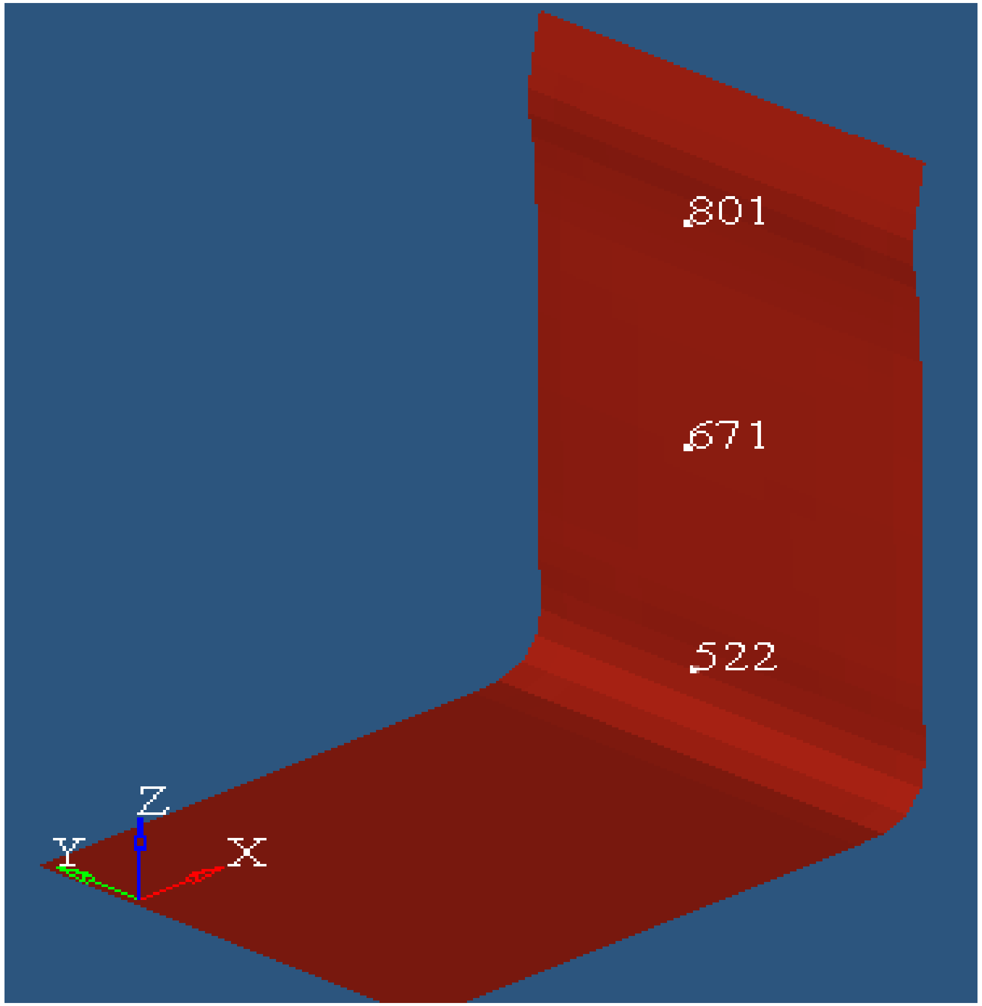
DOE RESULTS

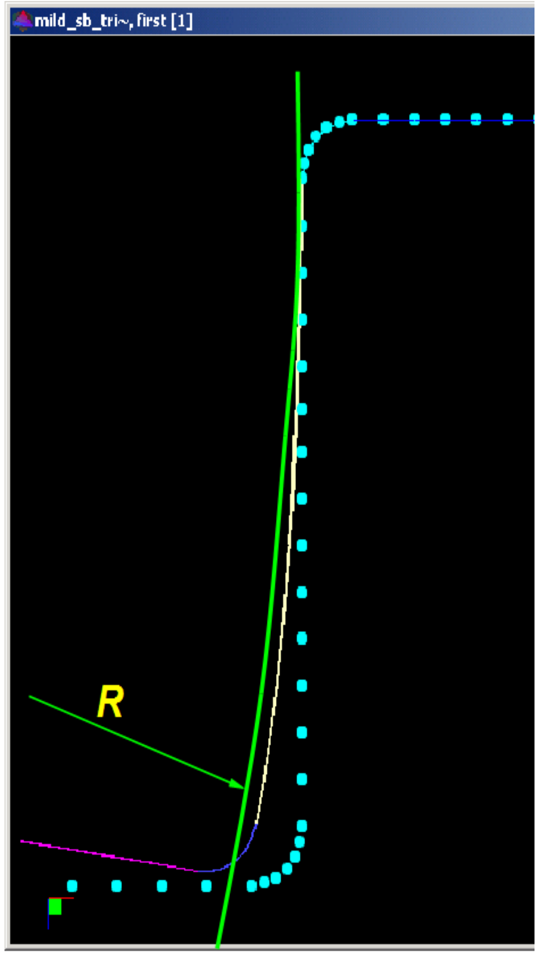
- Residual stress analysis
- Springback analysis
- Correlation

RESIDUAL STRESSES



SPRINGBACK ANALYSIS

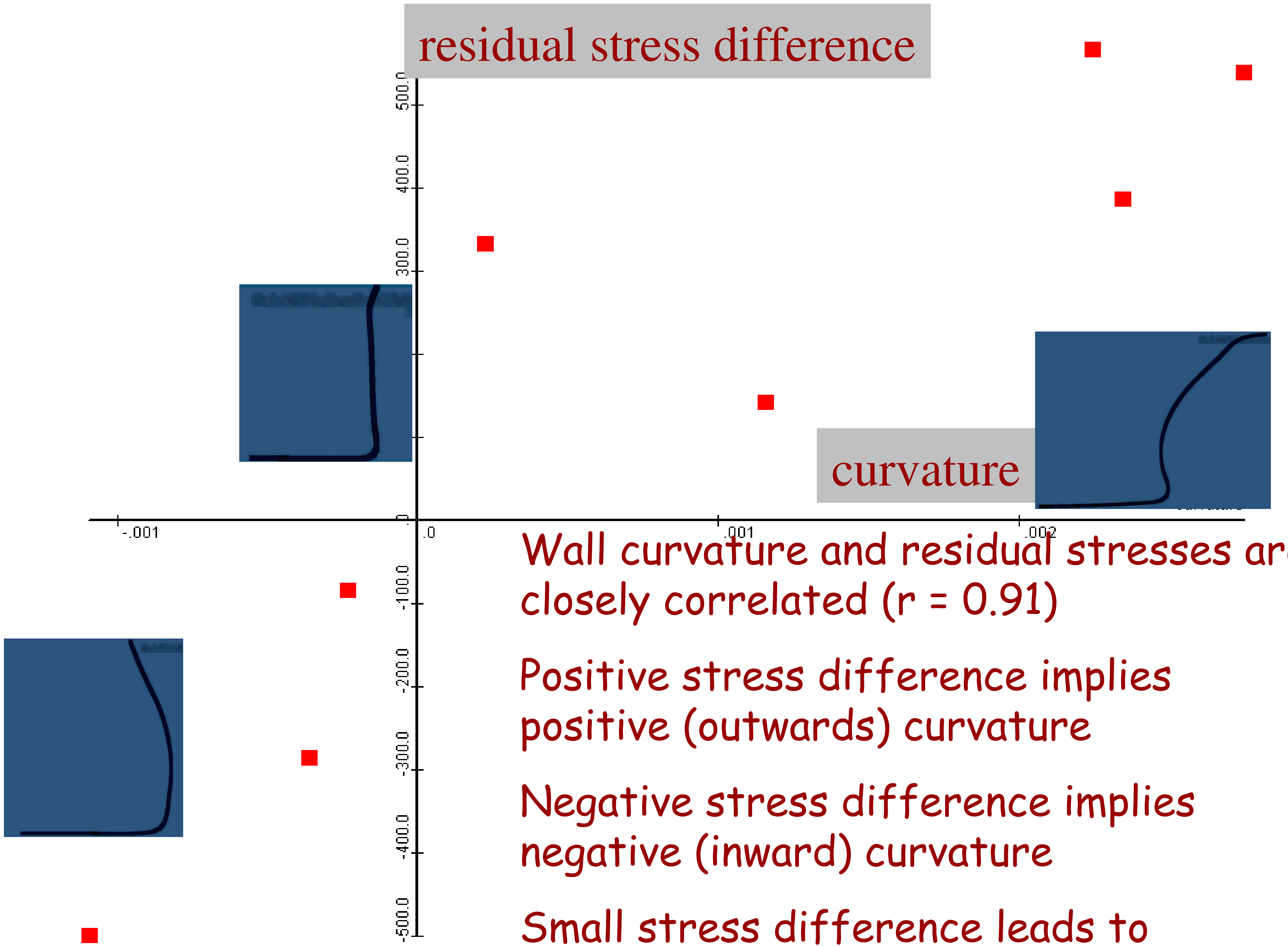




RESULT ANALYSIS

- Residual stresses vs. curvature/shape
- Shape vs. Material characteristics

Correlation curvature deltaSigma



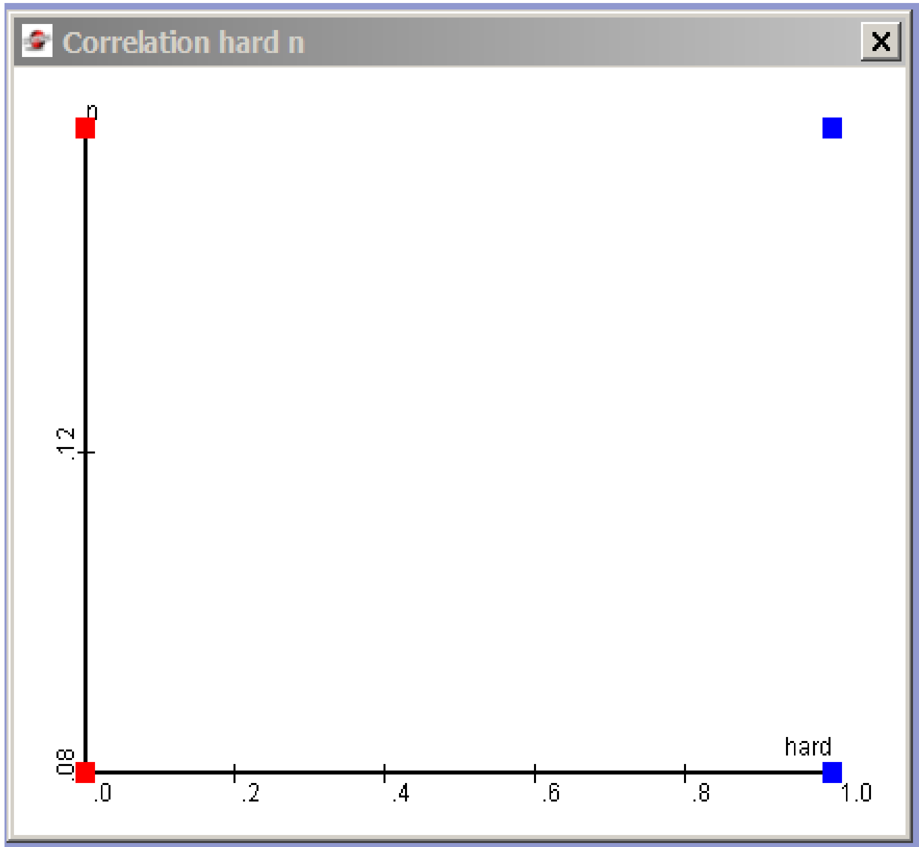
Wall curvature and residual stresses are closely correlated (r = 0.91)

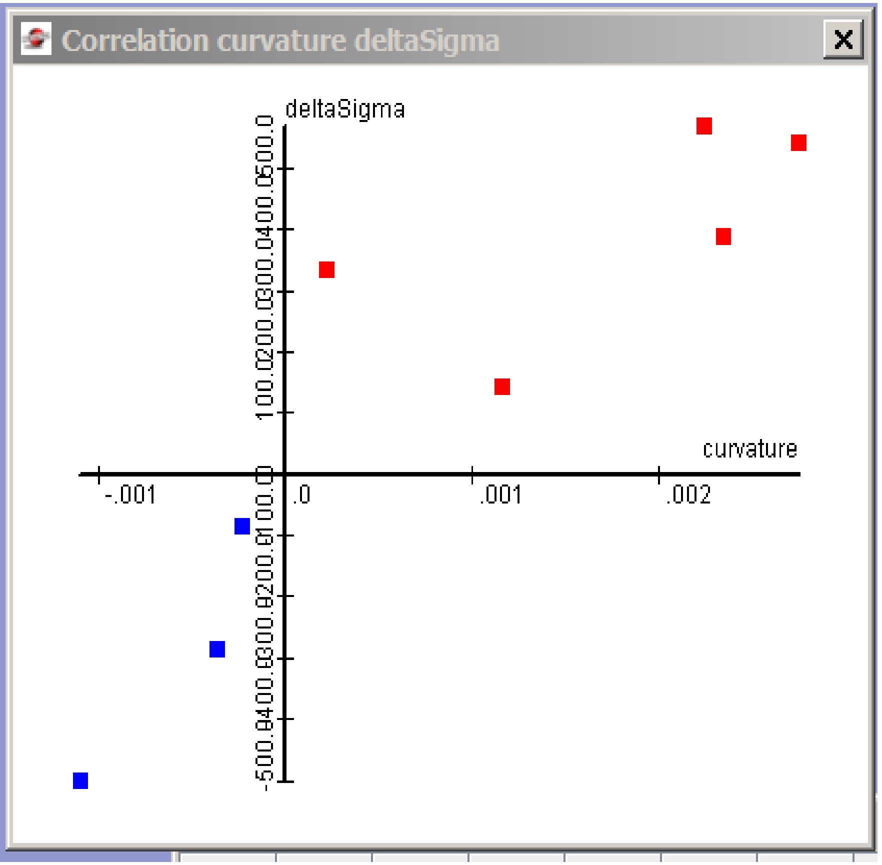
Positive stress difference implies positive (outwards) curvature

Negative stress difference implies negative (inward) curvature

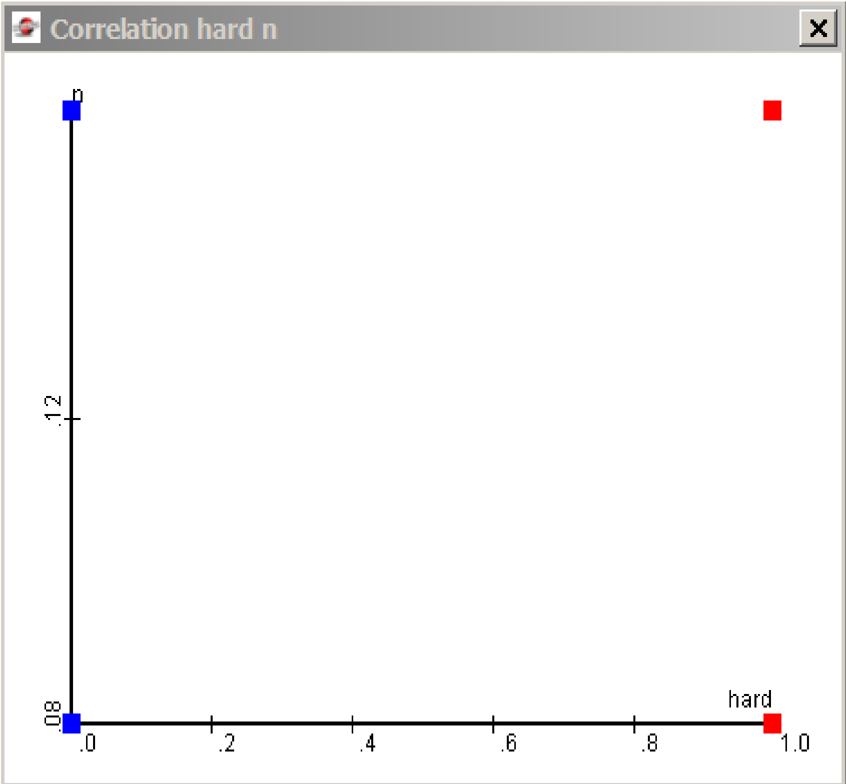
Small stress difference leads to straight walls after springback

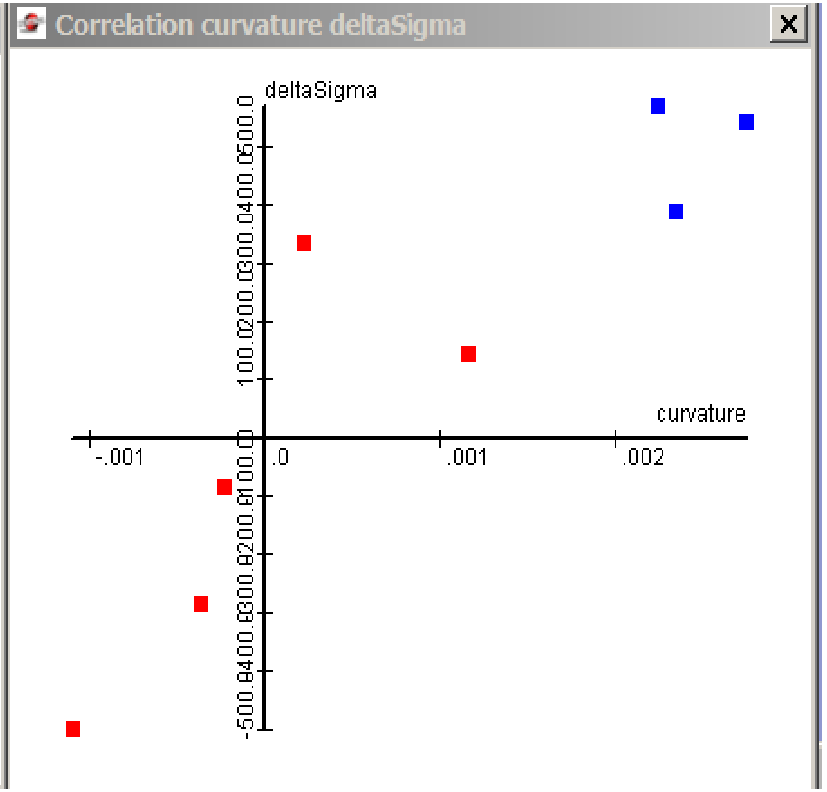
INWARD SPRINGBACK POINTS HAVE ALL KINEMATIC HARDENING





LARGE SPRINGBACK POINTS HAVE ALL ISOTROPIC HARDENING





CONCLUSIONS

- The evolution of the hardening surface is key to understanding springback
- Can we control springback choosing a right material ?