Some considerations in order to assess the mechanical properties of Nb after plastic deformation and heat treatment

Adrià Gallifa– EN/MME/Materials & Metrology (CERN)
Alexandre Amorim Carvalho - EN/MME/Engineering Design & Measurements

CERN – 13/12/2018

Concern

- Is a good approach to use Nb cold rolled sheets to assess the mechanical properties of a Nb sheet deformed by deep drawing?

- How to correlate the deformation state of the real deep drawn cavities with the deformation state of the cold rolled samples for the test campaign?

  - Effective plastic strain (equivalent Von Mises strain) ?
  - Stored plastic energy ?
  - Hardness ?
  - Density of dislocation ?
  - Residual stresses ?

Effective plastic strain (eq. Von Mises strain) in cold rolling

- Assumptions:
  - the cold rolling is performed in two perpendicular directions in steps of 5% thickness reduction.
  - V=constant.
  - Dimension in the perpendicular direction to rolling remains constant.

Dimensions in mm

initial sample	h0	l0	w0	volume
	4	100	100	40000

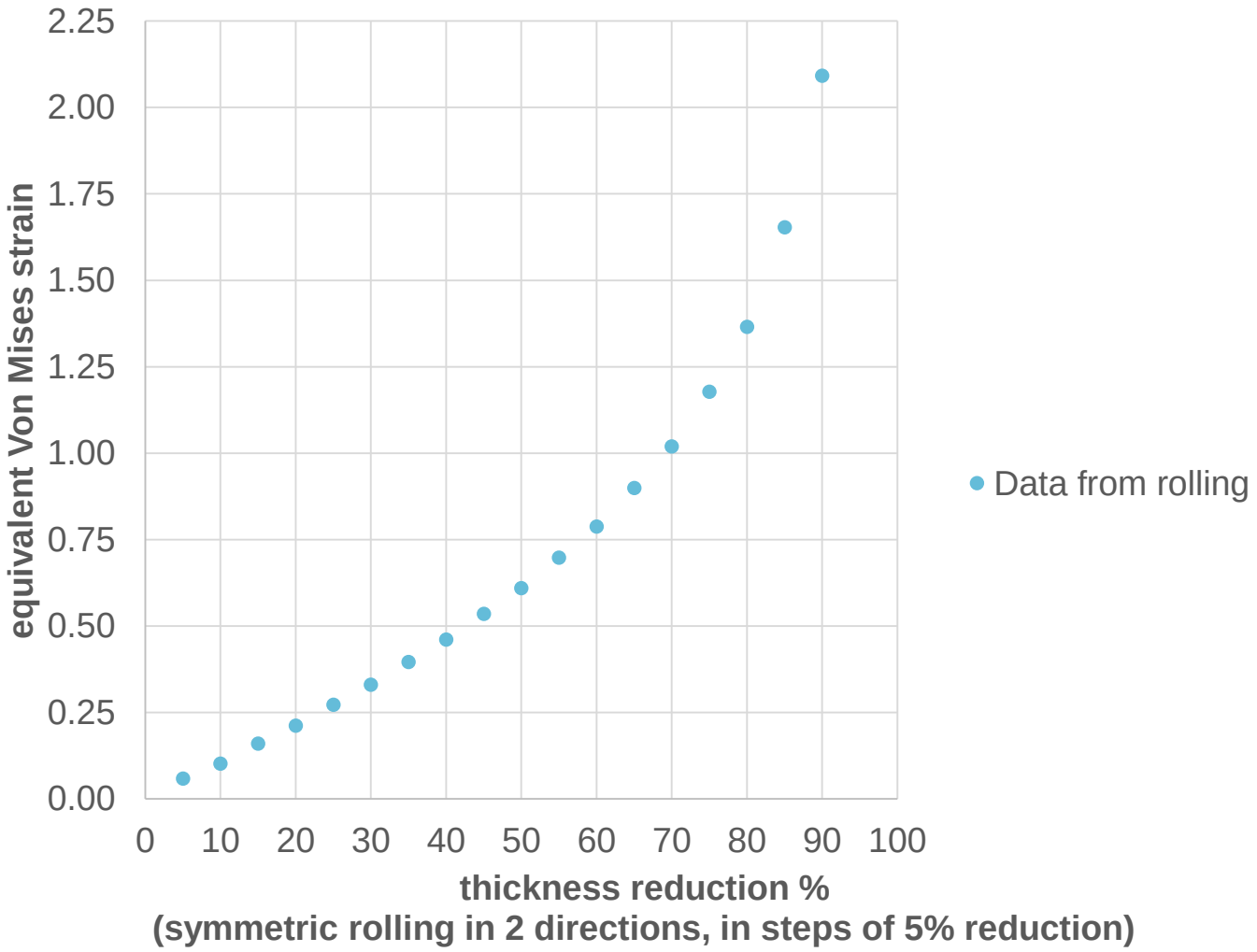
thickness reduction %	hf	lf	wf	e33	e11	e22	eq. VM strain
5	3.8	105.3	100.0	-0.05	0.05	0.00	0.06
10	3.6	105.3	105.6	-0.1	0.05	0.06	0.10
15	3.4	111.5	105.6	-0.15	0.11	0.06	0.16
20	3.2	111.5	112.2	-0.2	0.11	0.12	0.21
25	3	118.9	112.2	-0.25	0.19	0.12	0.27
30	2.8	118.9	120.2	-0.3	0.19	0.20	0.33
35	2.6	128.0	120.2	-0.35	0.28	0.20	0.40
40	2.4	128.0	130.2	-0.4	0.28	0.30	0.46
45	2.2	139.7	130.2	-0.45	0.40	0.30	0.54
50	2	139.7	143.2	-0.5	0.40	0.43	0.61
55	1.8	155.2	143.2	-0.55	0.55	0.43	0.70
60	1.6	155.2	161.1	-0.6	0.55	0.61	0.79
65	1.4	177.4	161.1	-0.65	0.77	0.61	0.90
70	1.2	177.4	187.9	-0.7	0.77	0.88	1.02
75	1	212.8	187.9	-0.75	1.13	0.88	1.18
80	0.8	212.8	234.9	-0.8	1.13	1.35	1.37
85	0.6	283.8	234.9	-0.85	1.84	1.35	1.65
90	0.4	283.8	352.4	-0.9	1.84	2.52	2.09
95	0.2	567.5	352.4	-0.95	4.68	2.52	3.28
99	0.04	567.5	1762.0	-0.99	4.68	16.62	10.38

The von Mises or equivalent strain ε_e is computed as:

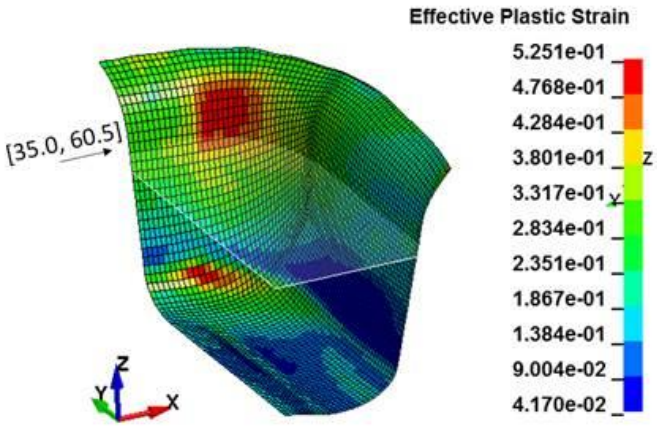
$$\varepsilon_e = \frac{1}{1+\nu}\left(\frac{1}{2}\left[(\varepsilon_1-\varepsilon_2)^2+(\varepsilon_2-\varepsilon_3)^2+(\varepsilon_3-\varepsilon_1)^2\right]\right)^{\frac{1}{2}}$$

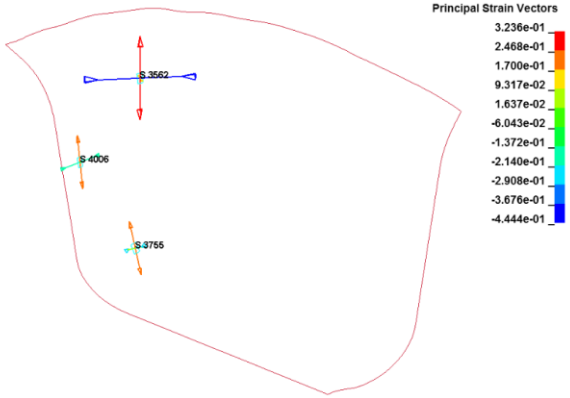
Source: Ansys 17.0 code: https://www.sharcnet.ca/Software/Ansys/17.0/en-us/help/wb_sim/ds_Equiv_Stress.html

Effective plastic strain (eq. Von Mises strain) in cold rolling



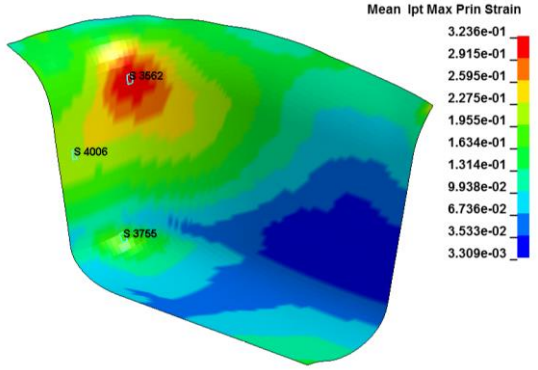
Effective plastic strain (eq. Von Mises strain) in deep drawn part



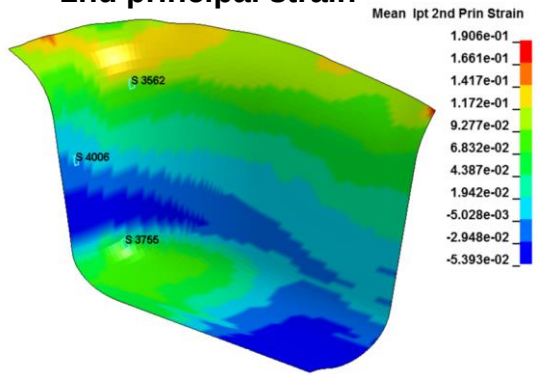


Data from simulations	e33	e11	e22	eq. VM strain
element 3562	-0.43	0.32	0.1	**0.45**
element 3755	-0.27	0.2	0.06	**0.28**
element 4006	-0.2	0.209	-0.005	**0.24**

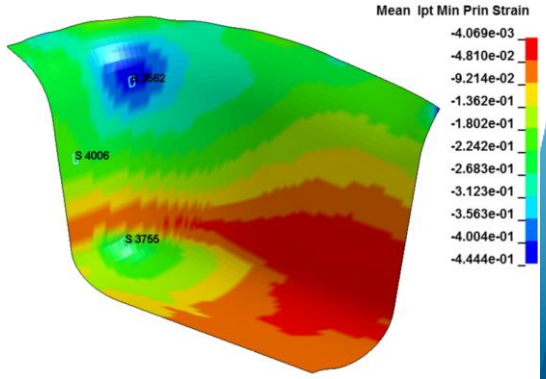
1st principal strain



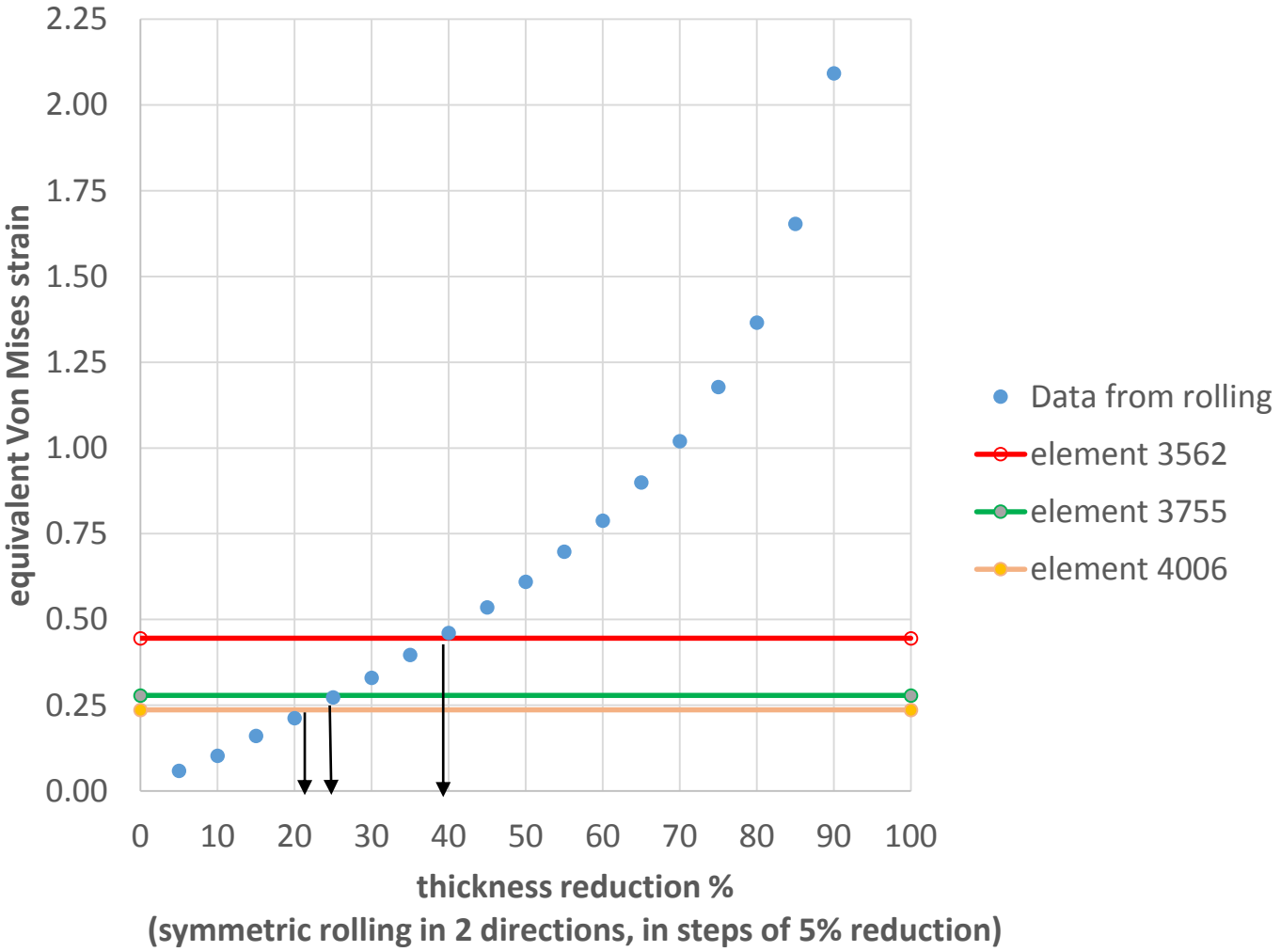
2nd principal strain



3rd principal strain



Thickness reduction to achieve desired deformation state



End