On Buckling of Thin Foils

Talk given at Politechnico di Milano, Orationem Meam.

Ståhle, P.

2019

Document Version:
Förlagets slutgiltiga version

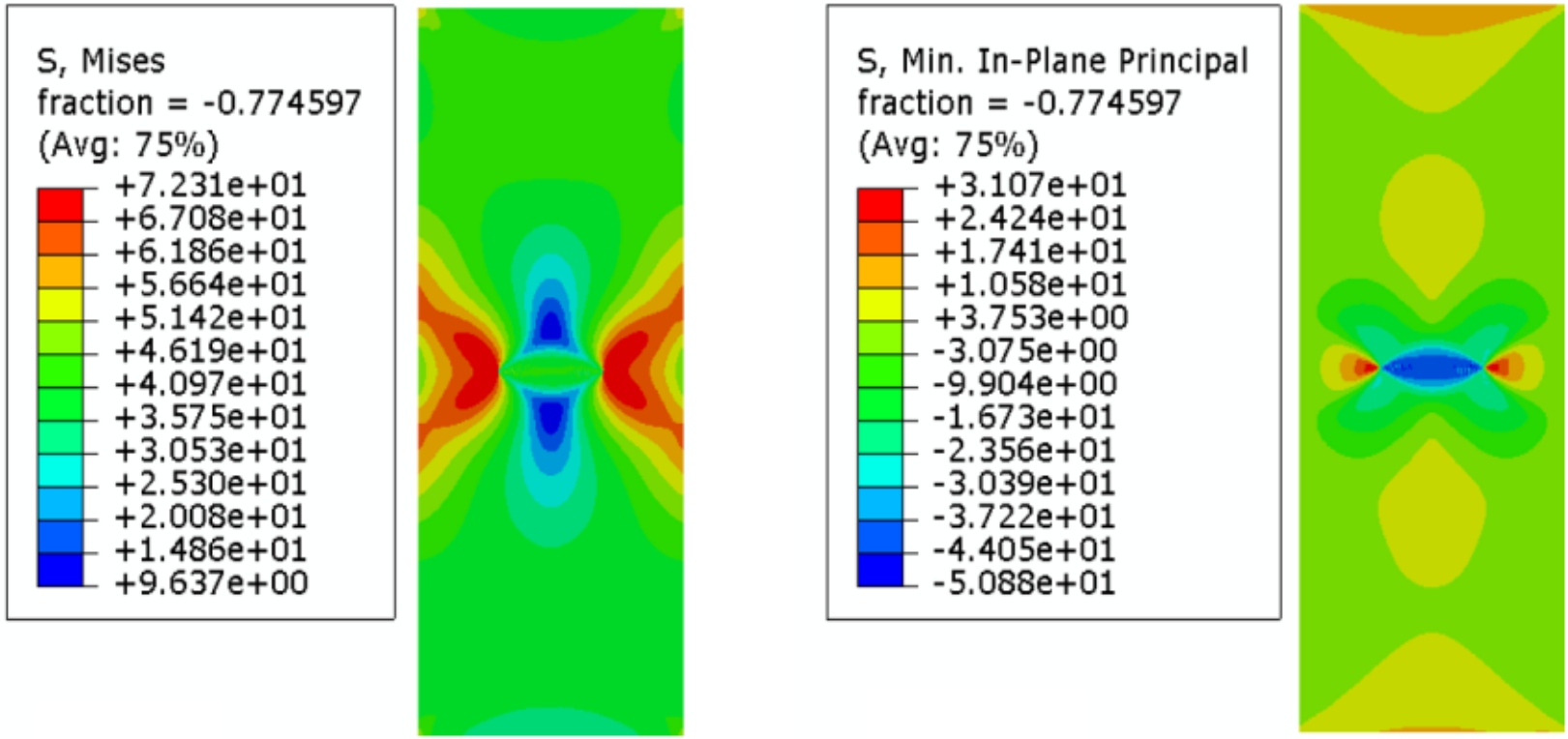
Gruppo Gabriella, Milano

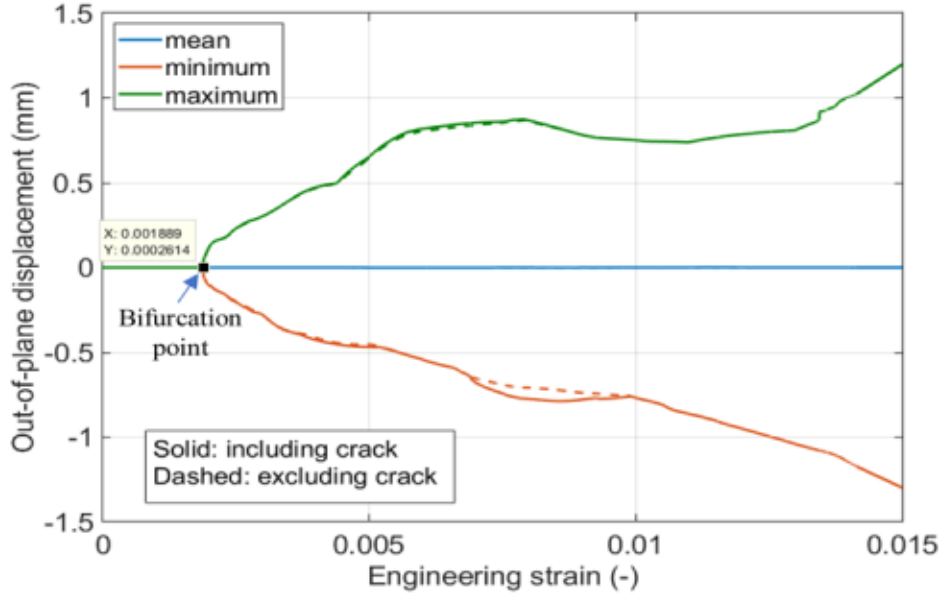
January 28th, 2019

1. Buckling and reduction of energy release rate
Politecnico di Milano, BTH, LU

2. Eskil's favourites - picks from his thesis

'Mises stress and Min. principle stress at bifurcation point:





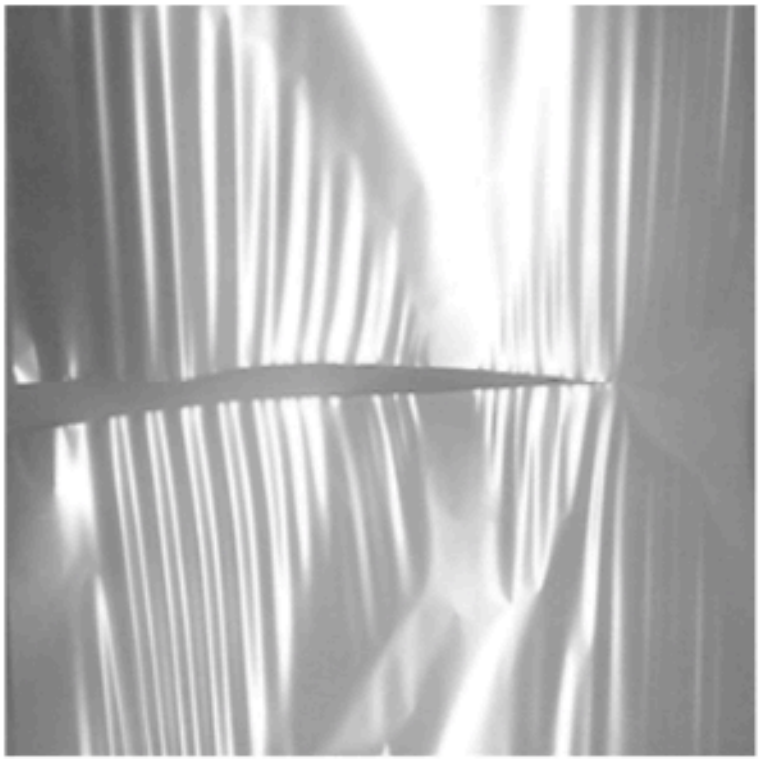


FIGURE 3. Buckling pattern

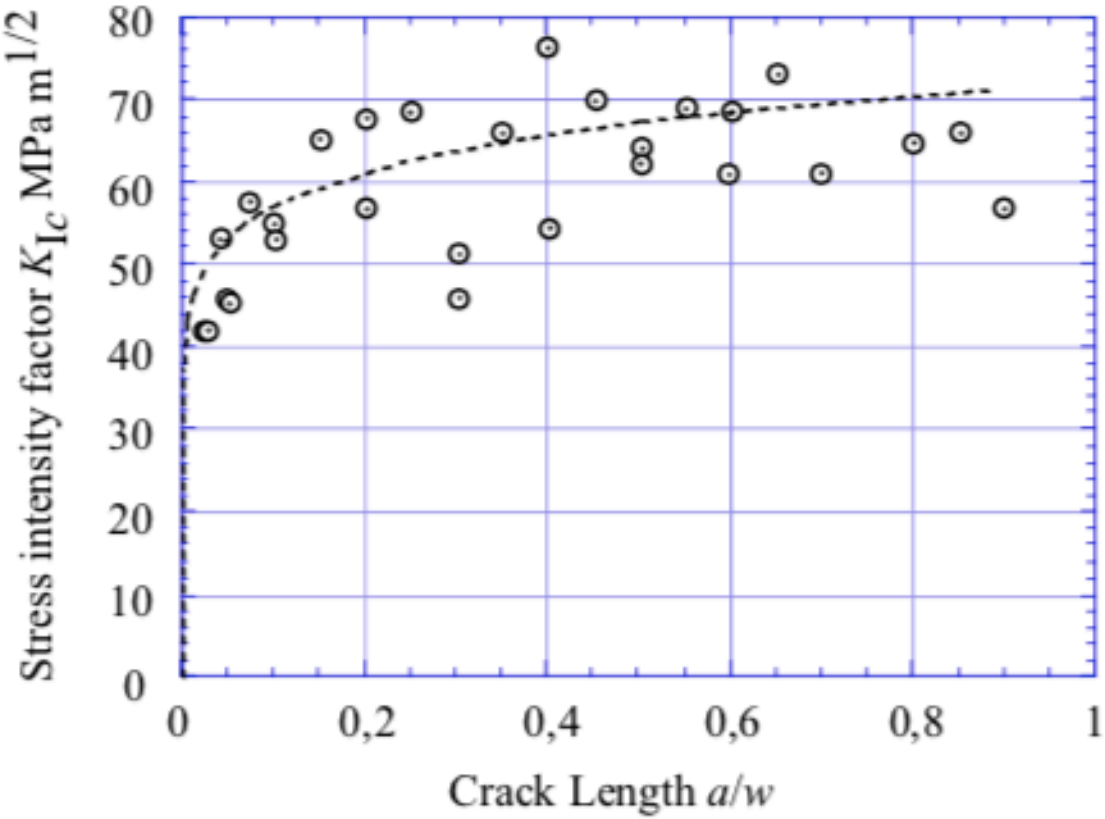
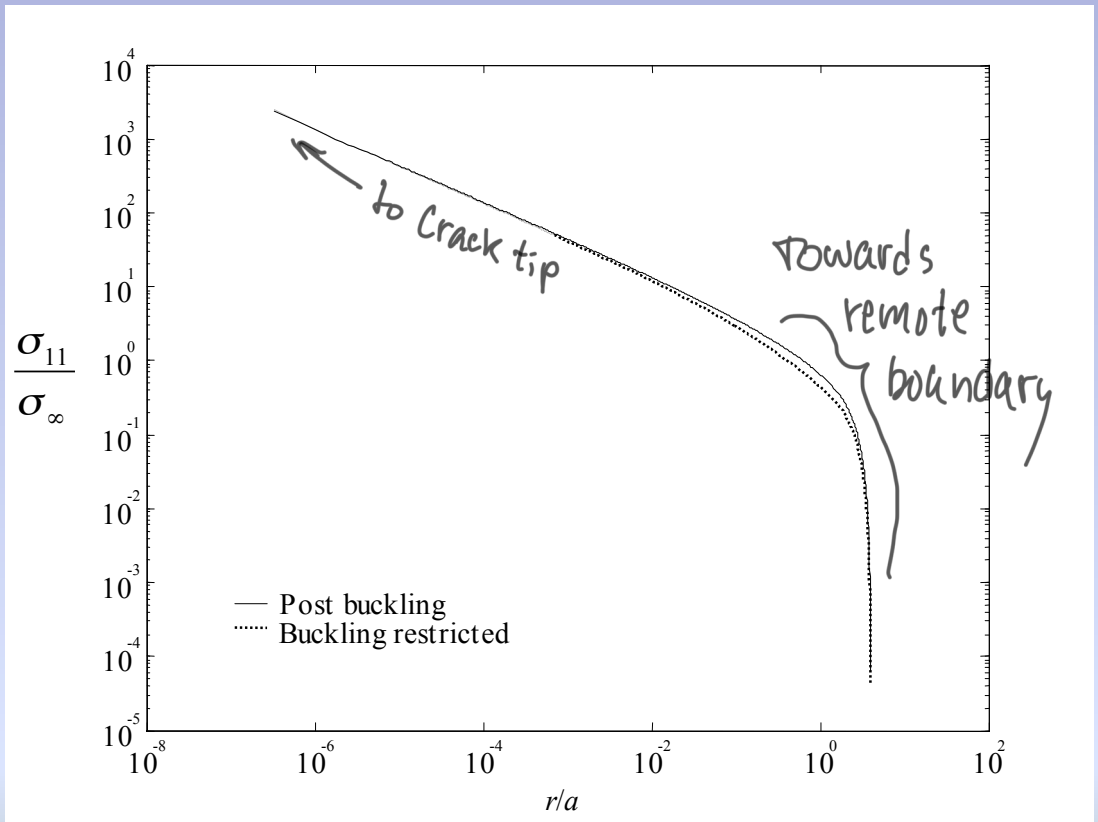
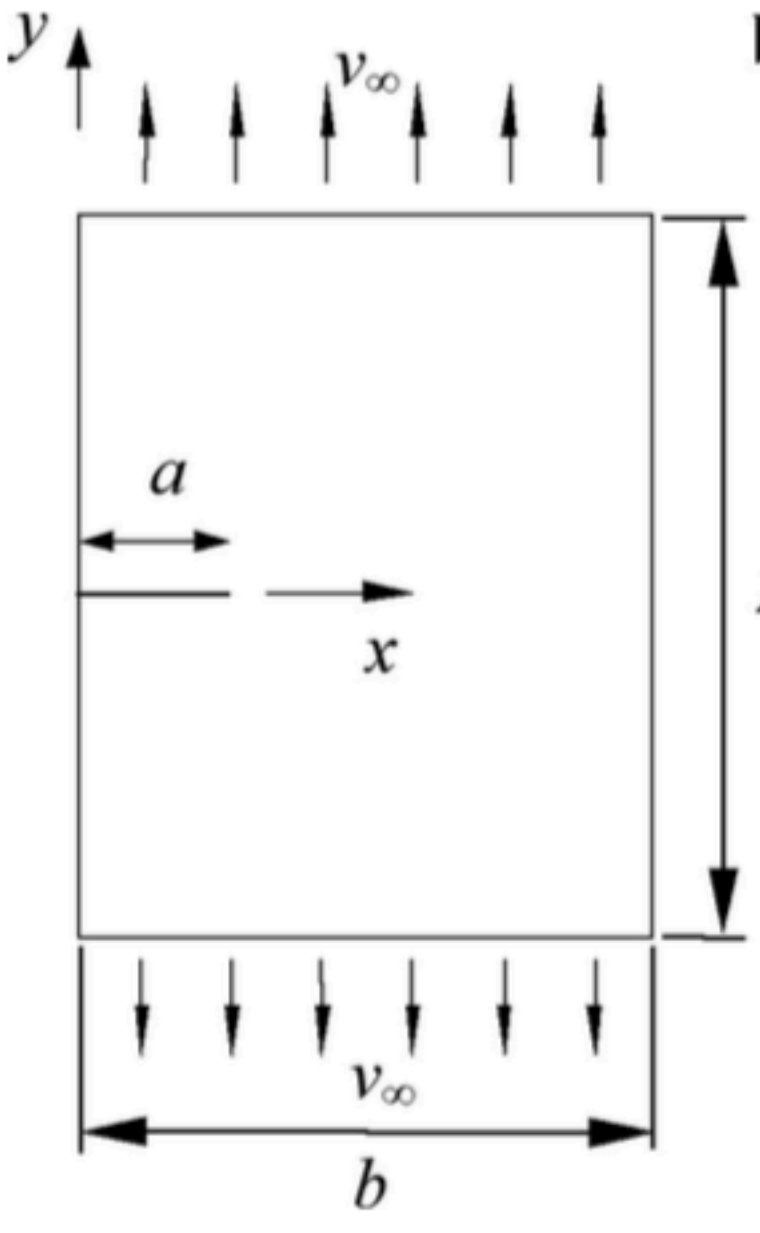
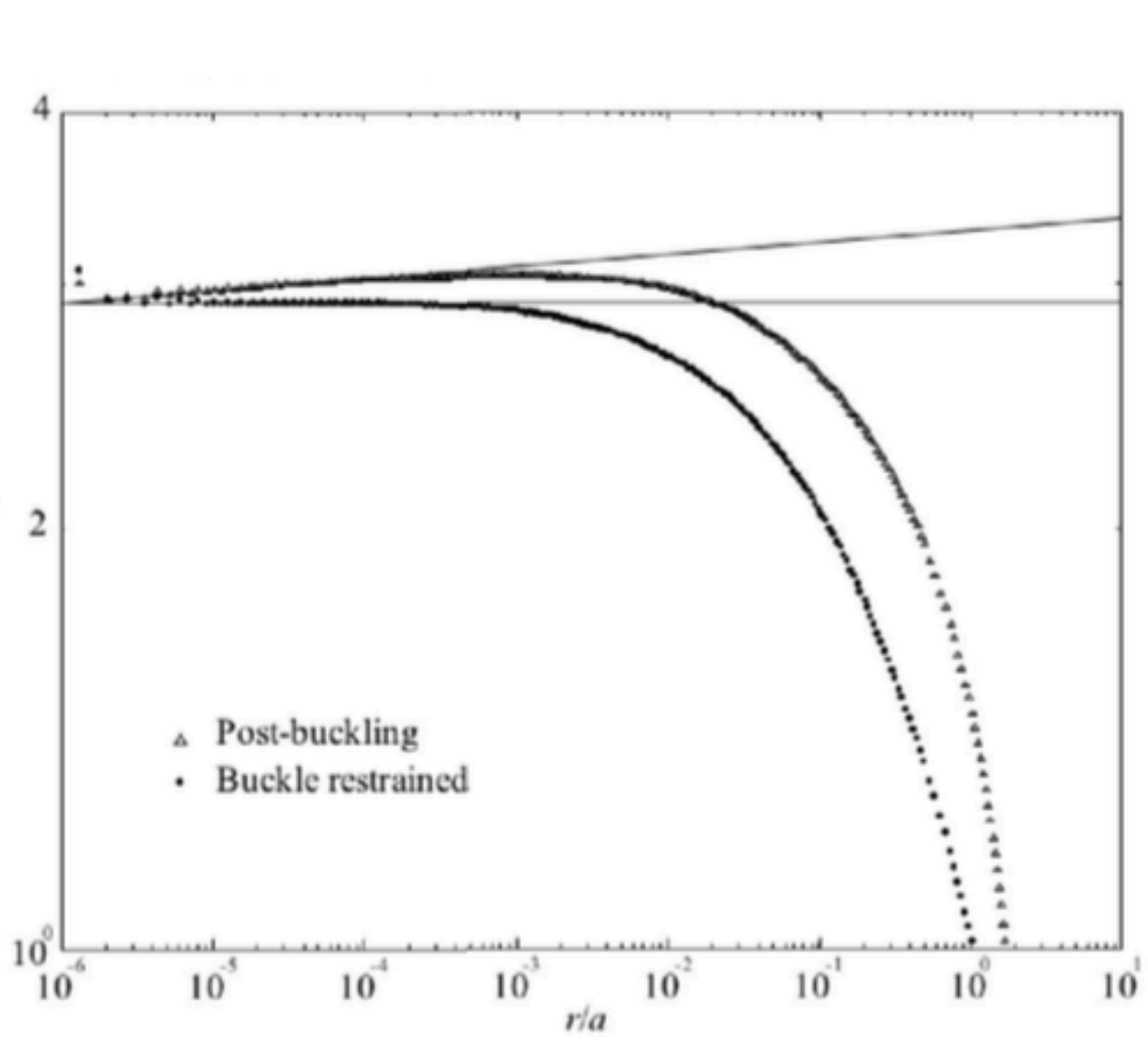


FIGURE 4. K_{Ic} results for the different tests. Dashed curve shows the theoretical result for $s = 0.4$.

- Central crack Denser case, *a/b* = 0.1




y
v_∞
a
x
2h
v_∞
b


b
4
2
10^0
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^0
10^1
r/a
Post-buckling
Buckle restrained

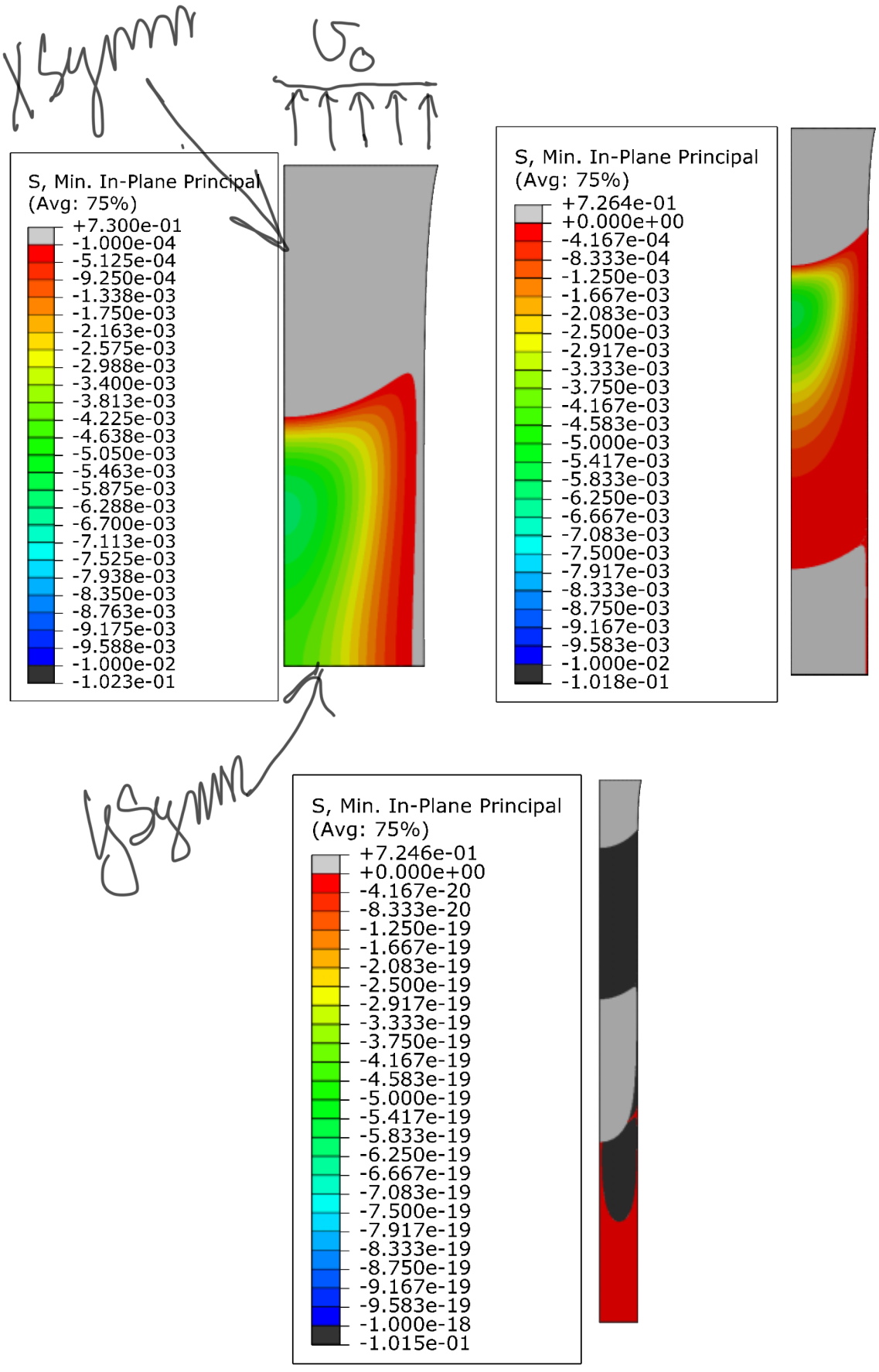
Influences on fracture criteria prediction

- The load capacity can be determined as:

$$\sigma_c = \frac{k_c \sigma_o (2\pi a / r_o)^s}{f(a/b, h/b)}$$

- The micro structural distance : $r_o = K_{Ic}^2 / \sigma_o^2$

- At a critical load the load parameter $k = k_c = K_I/K_{IC}$



Same condition as earlier studies (Except deformation is not exactly scaled).

L=length, W=width, $r = \frac{L}{W}$.

For r=2.5 compressive stress order 1e-3. For r=5 no compressive stress. For r=10 compressive stress is back and is in the order 1e-19.

Conclusion: Probable 'r' value to neglect clamp effect at the centre region, $2.5 < r < 5$

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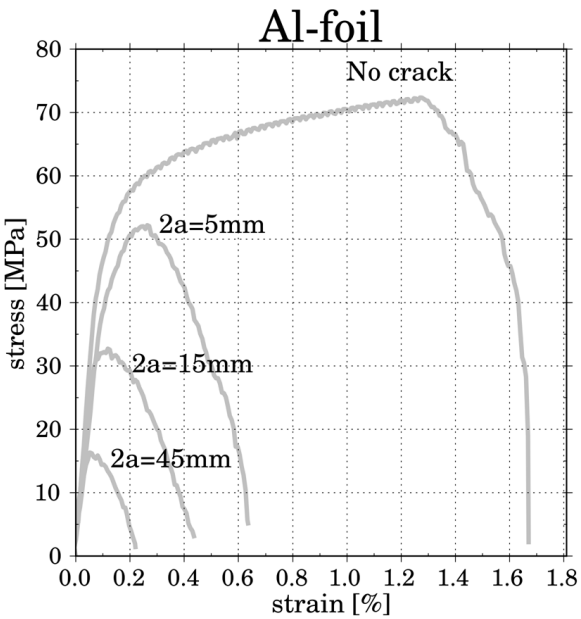
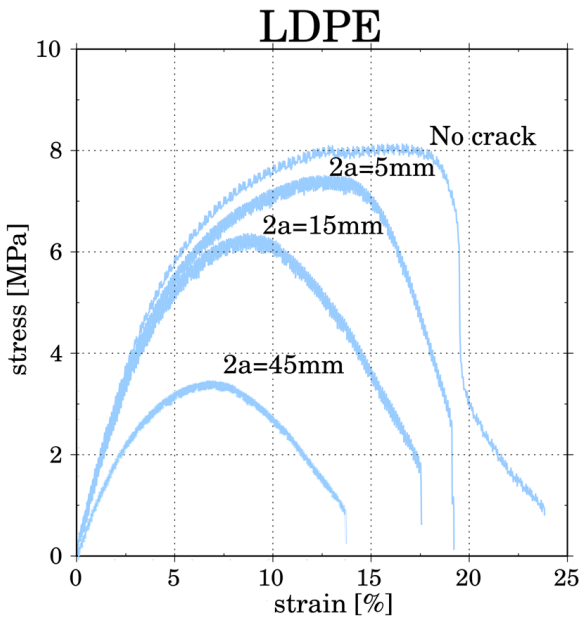
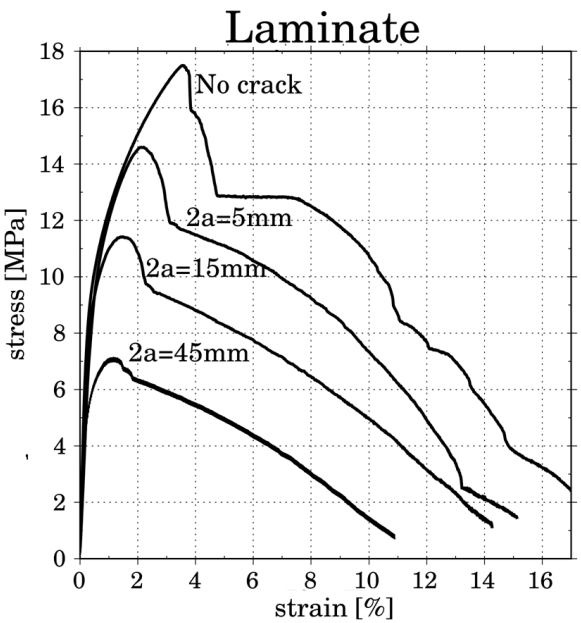
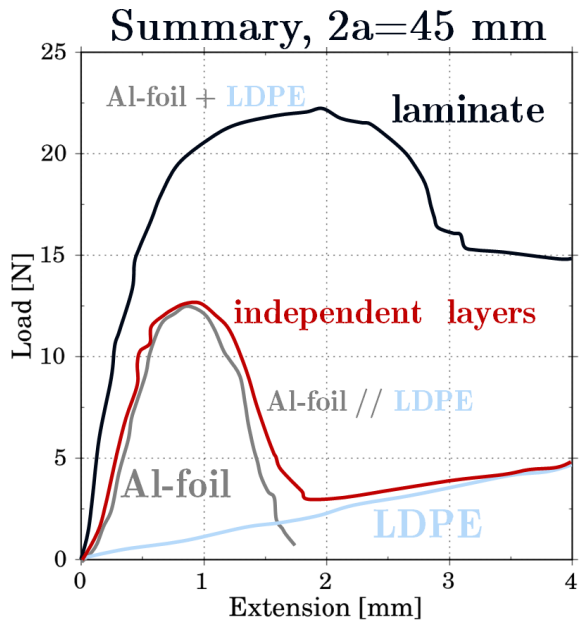
Test results





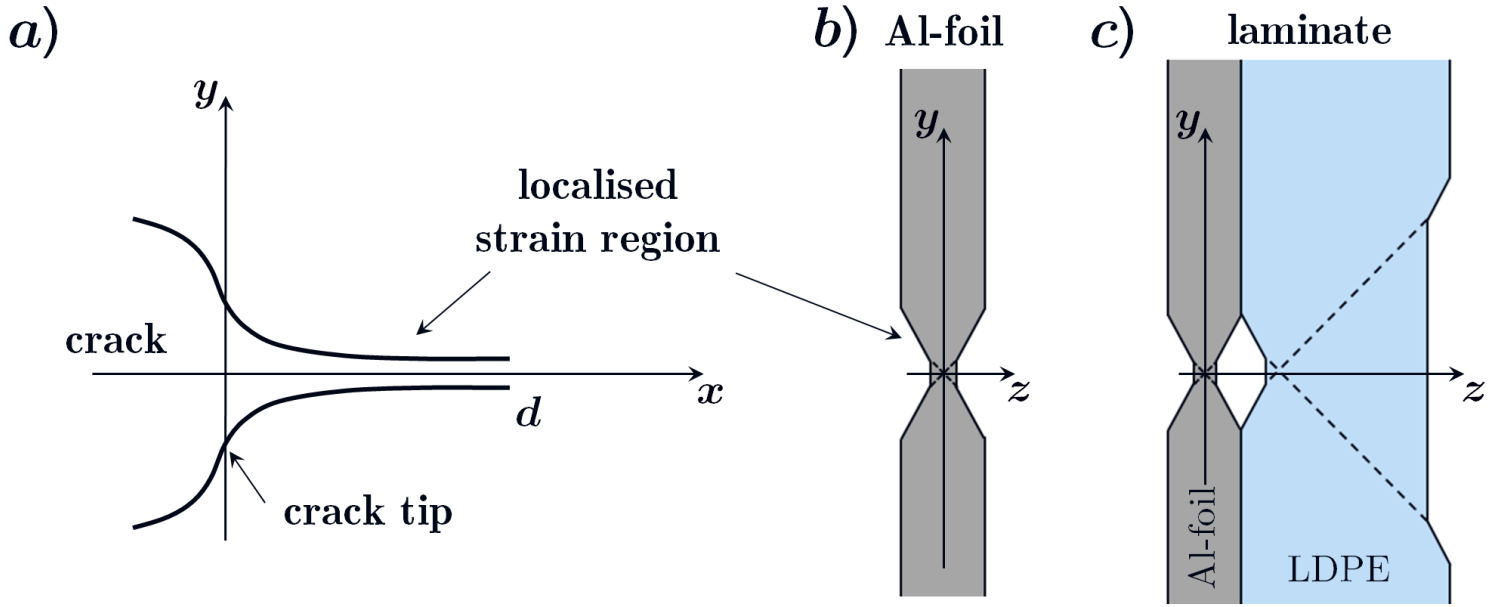
Stress vs. strain for tensile tests
a) Al-foil, b) Polymer





a) Stress vs. strain for the laminate. b) Load vs. extension. Summary of the aluminium, polymer and laminate results. Crack length 45mm (Kao-Walter et al., 2002), (Hutchinson, 2013)

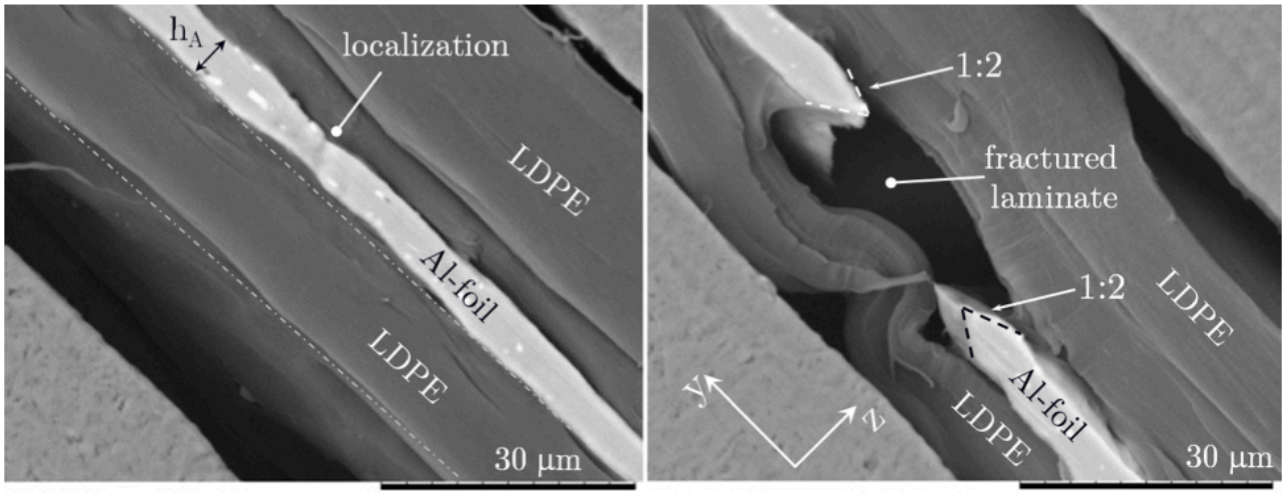
Work of failure

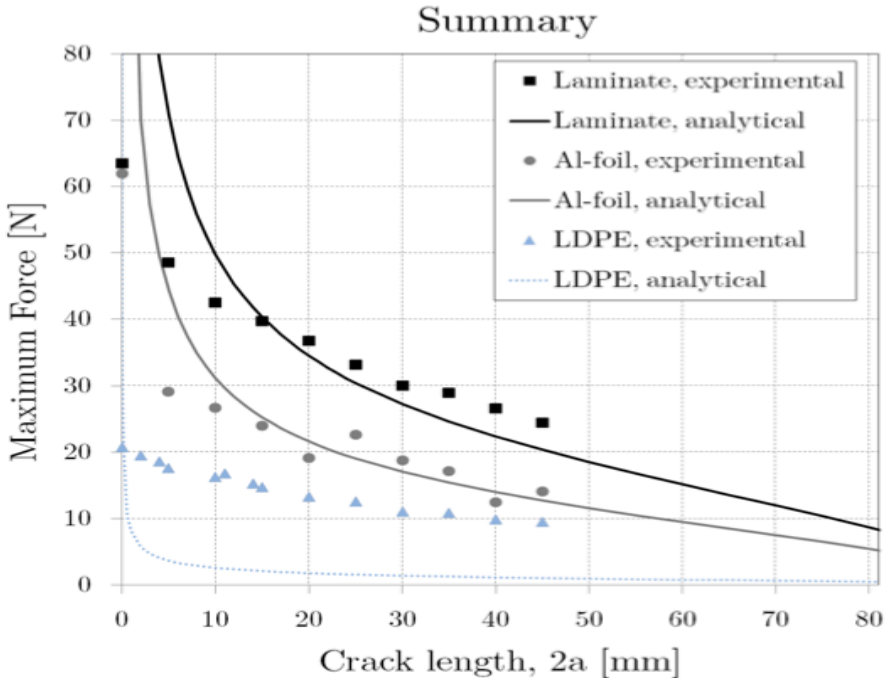


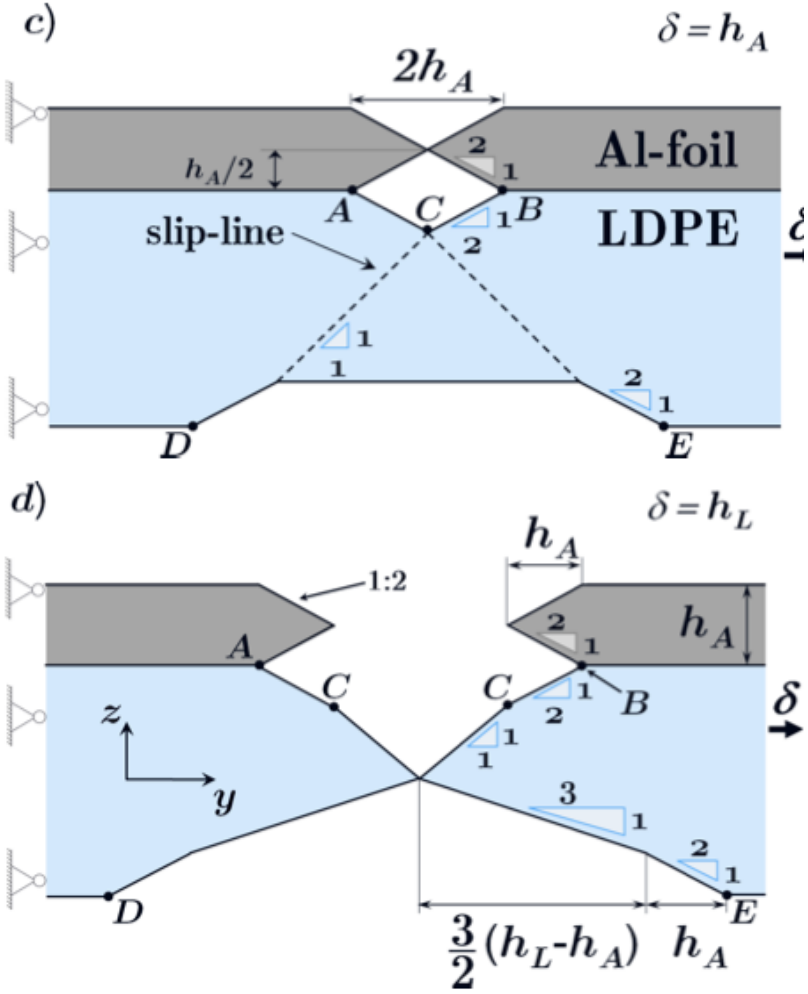
Strip yield zone ahead a crack tip. a) the crack geometry in the plane $z = 0$. b and c) the slip region as seen in a plane $x = \text{const}$.

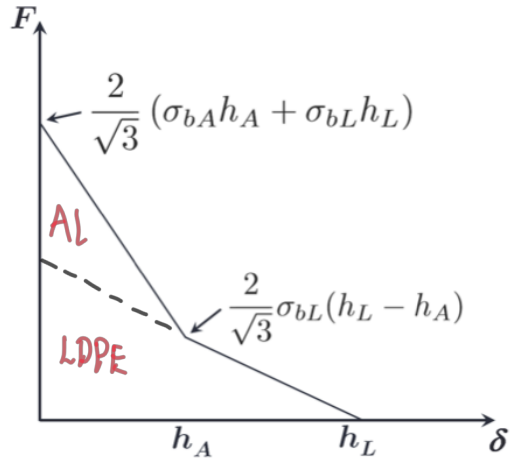
Super-tough Thin Film Laminates

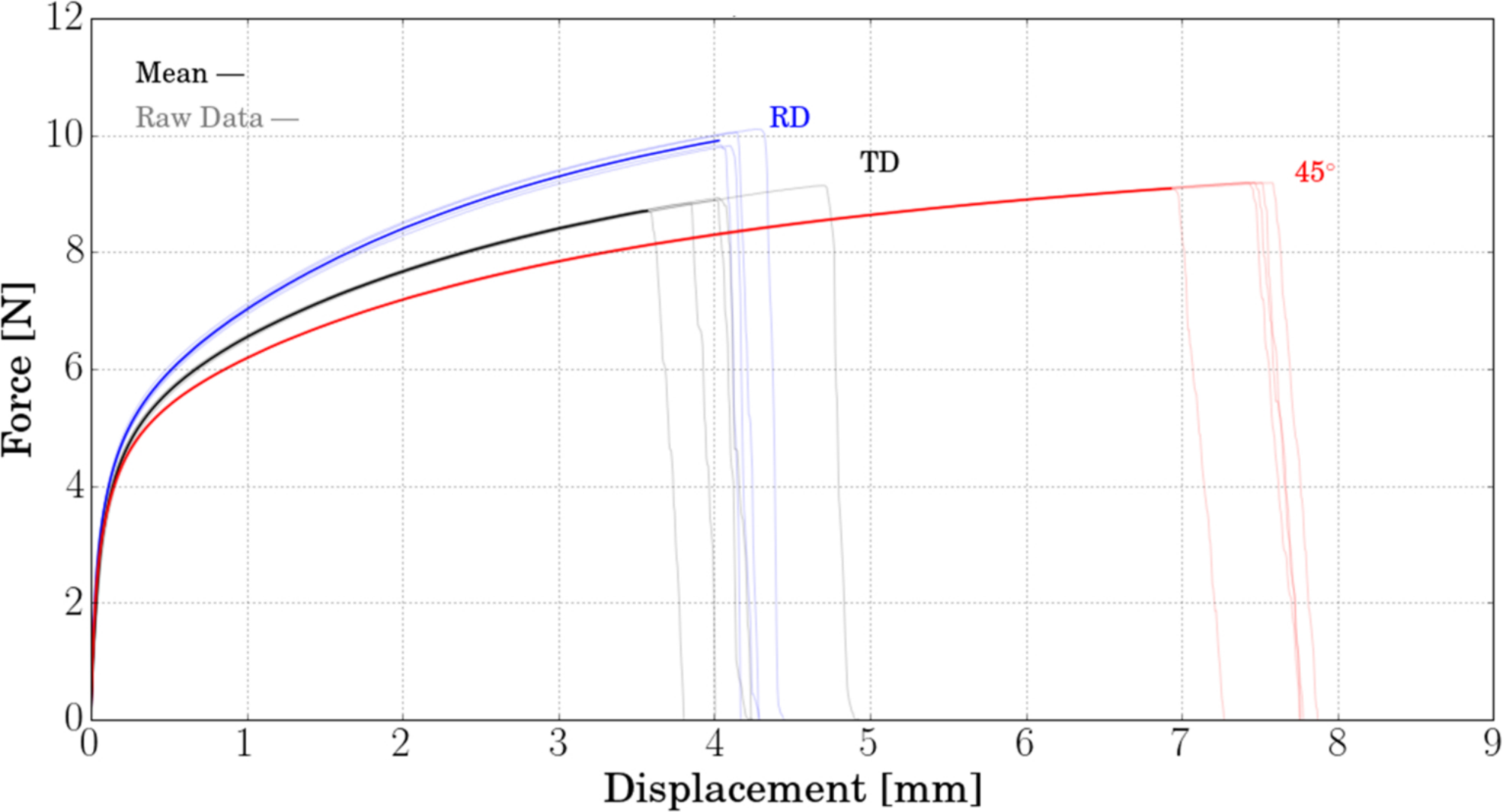
Sharon Kao-Walter, Rickard Hägglund, Eskil Andreasson

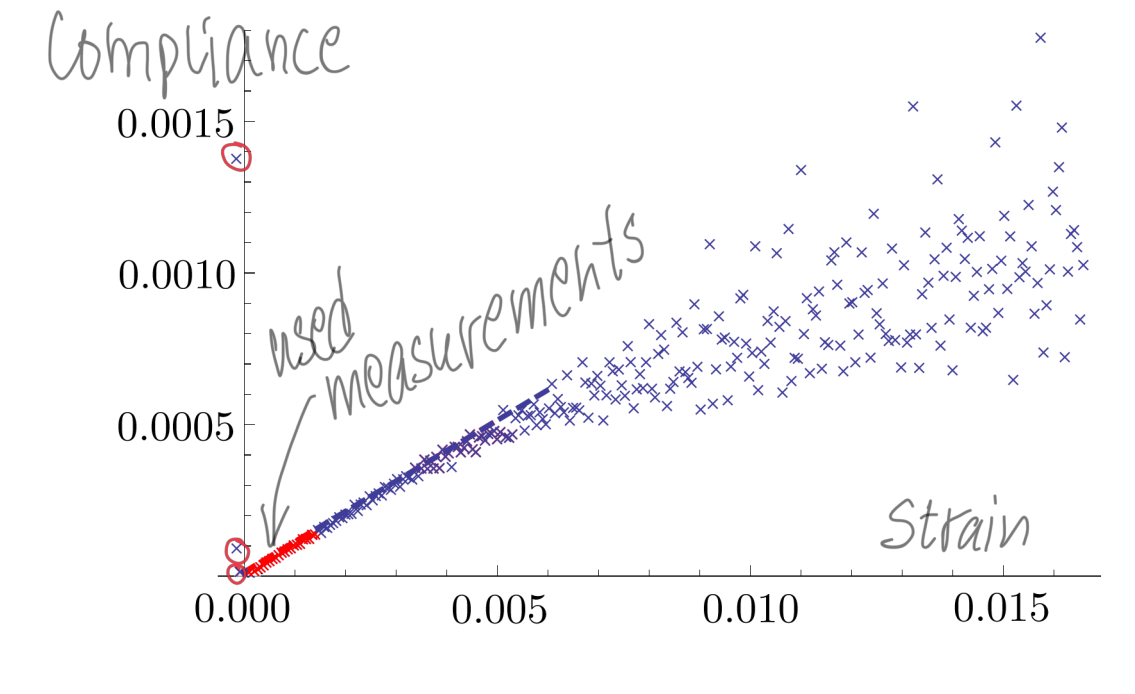


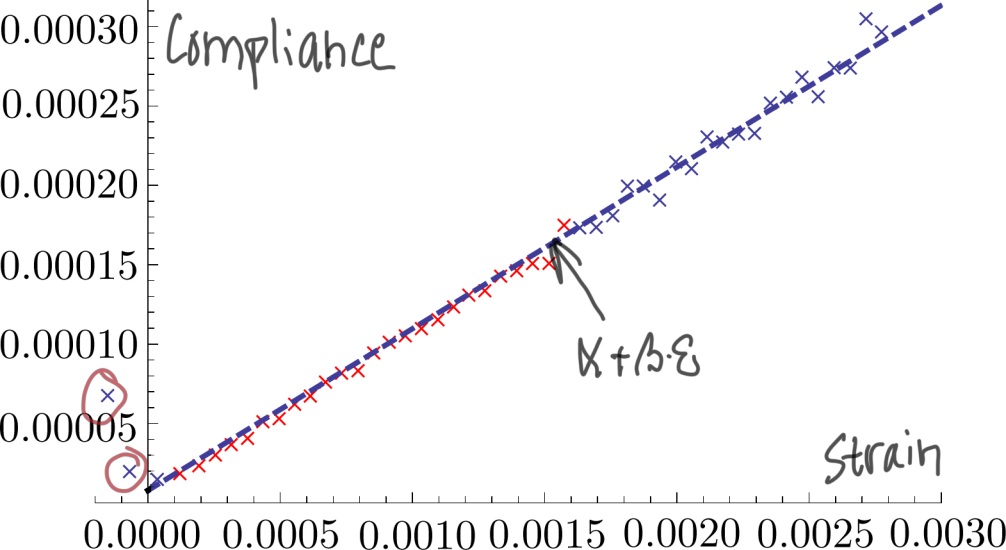


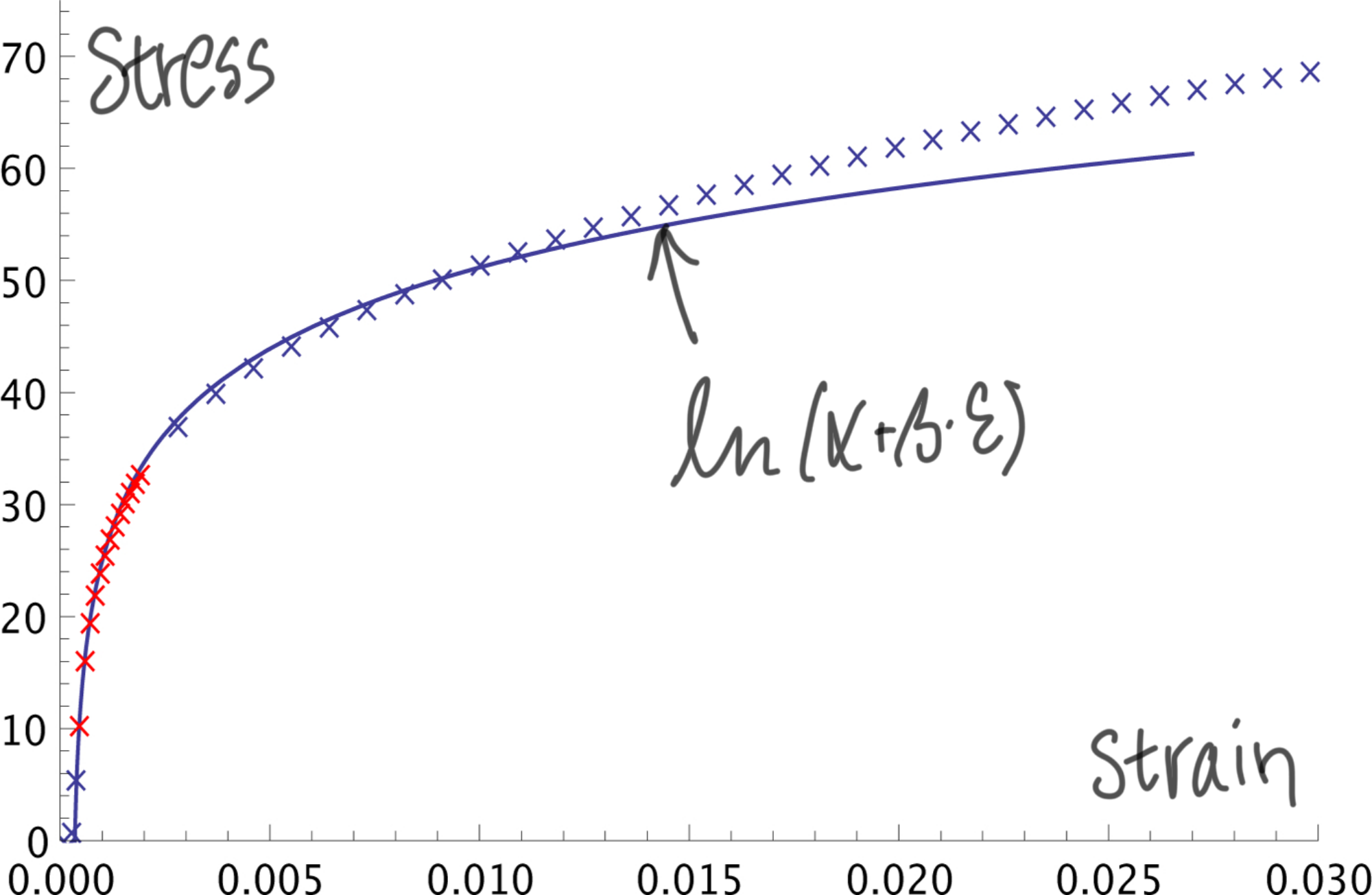


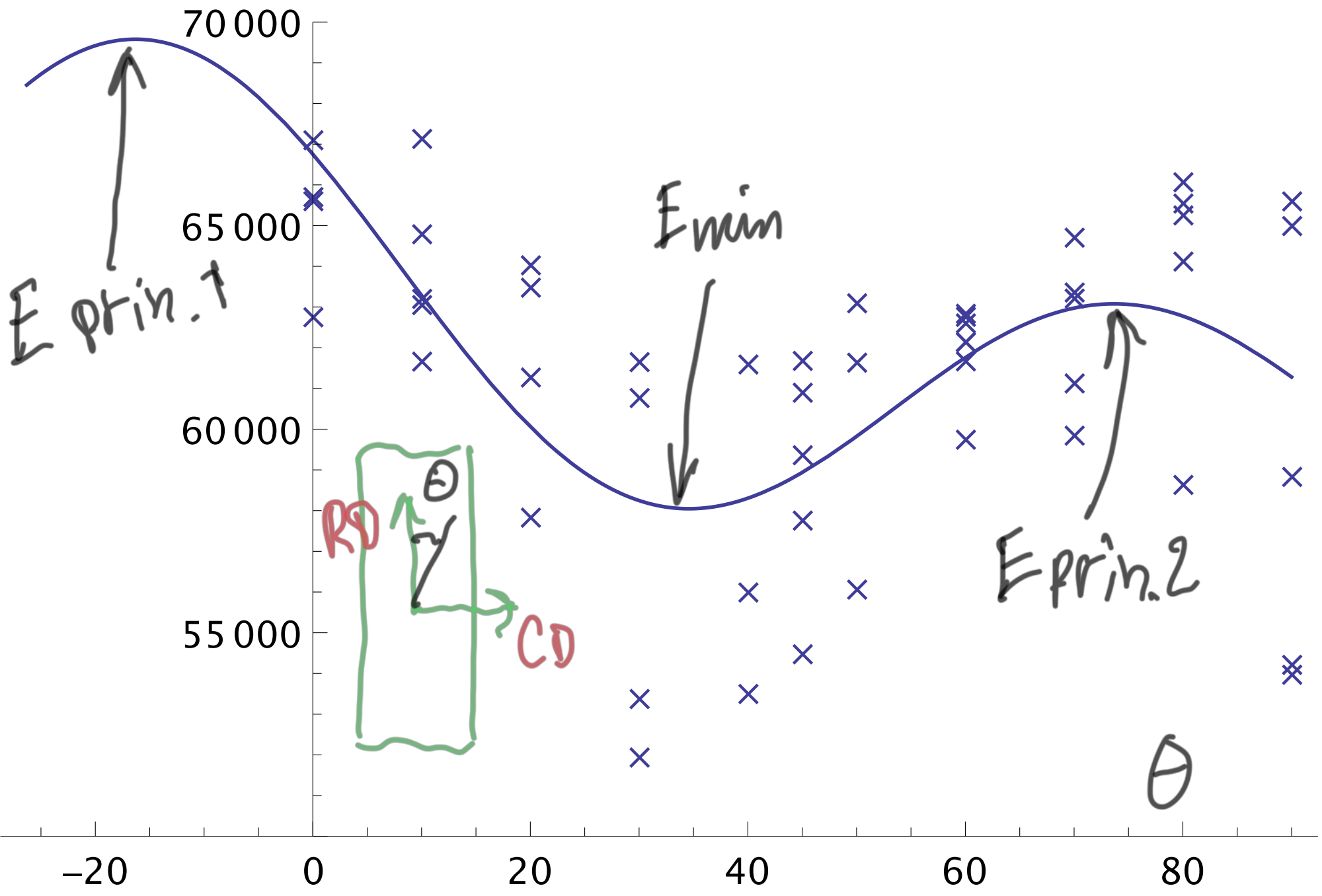



Mean —
Raw Data —
RD
TD
45°
Force [N]
Displacement [mm]
0
2
4
6
8
10
12
0
1
2
3
4
5
6
7
8
9


Compliance
0.0015
0.0010
0.0005
used measurements
Strain
0.000
0.005
0.010
0.015


Compliance
Strain
K+B·ε
0.00030
0.00025
0.00020
0.00015
0.00010
0.00005
0.0000
0.0005
0.0010
0.0015
0.0020
0.0025
0.0030


Stress
70
60
50
40
30
20
10
0
$\ln(K+B\cdot\varepsilon)$
Strain
0.000
0.005
0.010
0.015
0.020
0.025
0.030


70 000
65 000
60 000
55 000
−20
0
20
40
60
80
E prin.1
Emin
E prin.2
θ
RD
θ
CD