

Fine increment hole-drilling method for residual stress measurement, proposal of a calibrating apparatus

E. Valentini (SINT Technology, Italy)

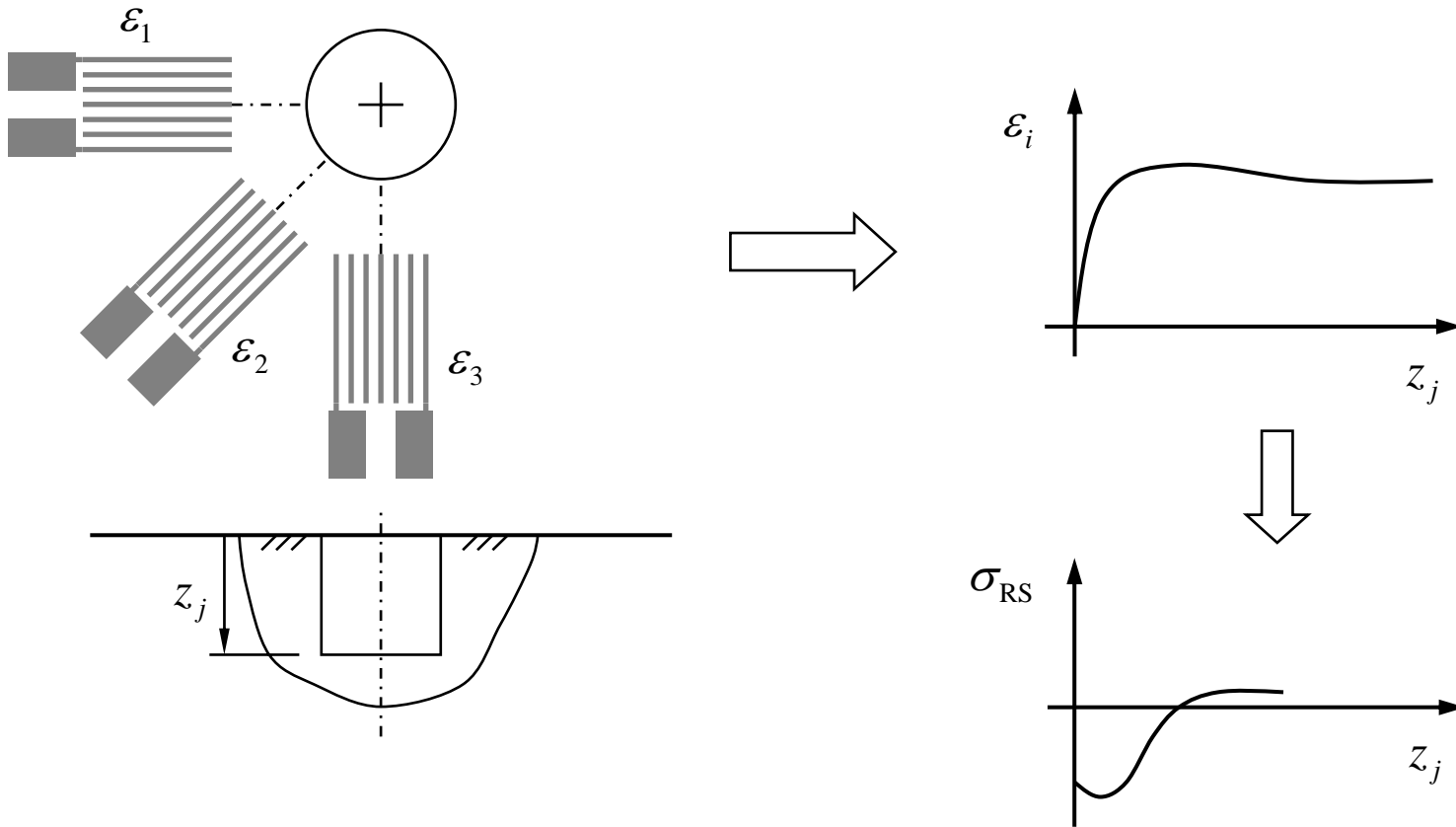
M. Benedetti, V. Fontanari (University of Trento, Italy)

M. Beghini, L. Bertini, C. Santus (University of Pisa, Italy)

Contents:

- Increment hole-drilling tool (RESTAN)
- Bending apparatus for measure verification
- Shot Peening on Aluminum Alloy specimens
- Comparison with X-ray

Increment hole-drilling method



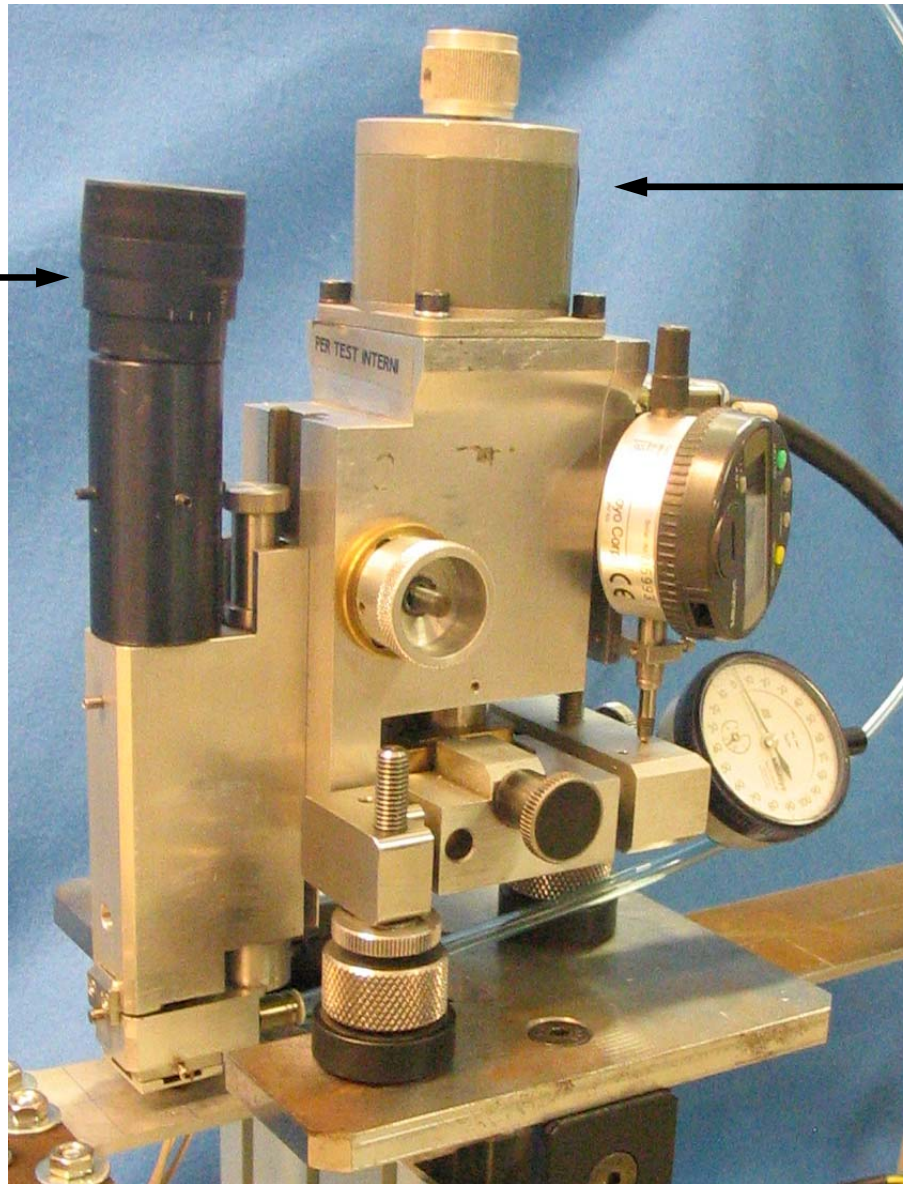
Let's double check !

REsidual STress ANalyzer (RESTAN)



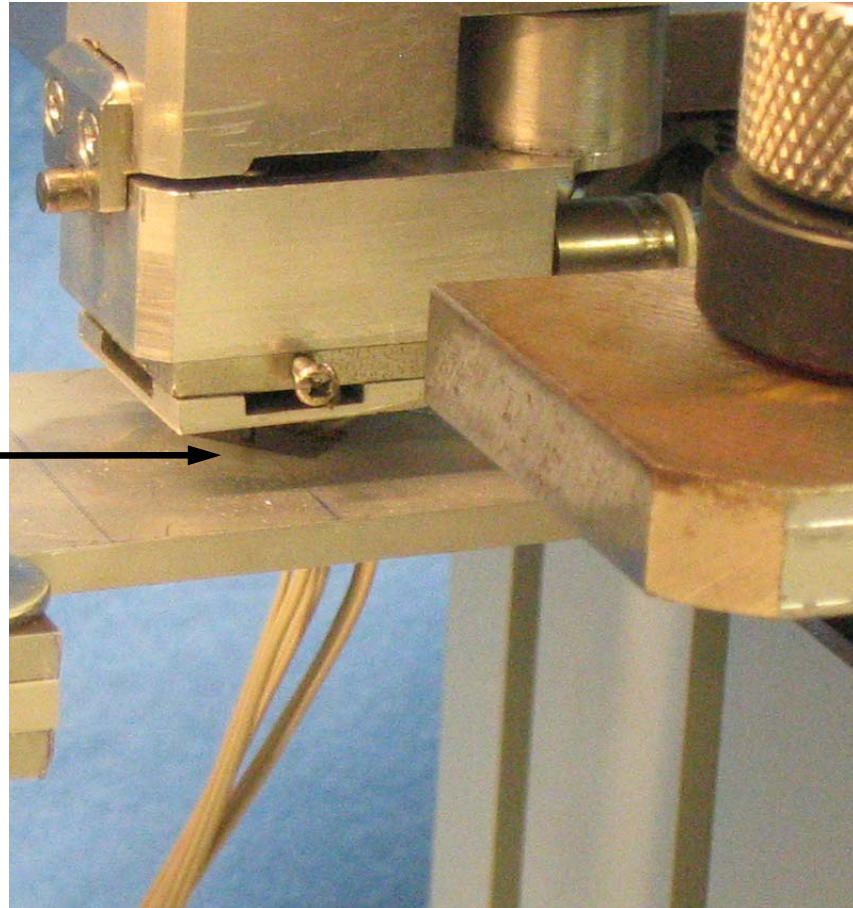
<http://www.sintechnology.com/index.htm>

Reduced eccentricity, through a monocular and cross hairs

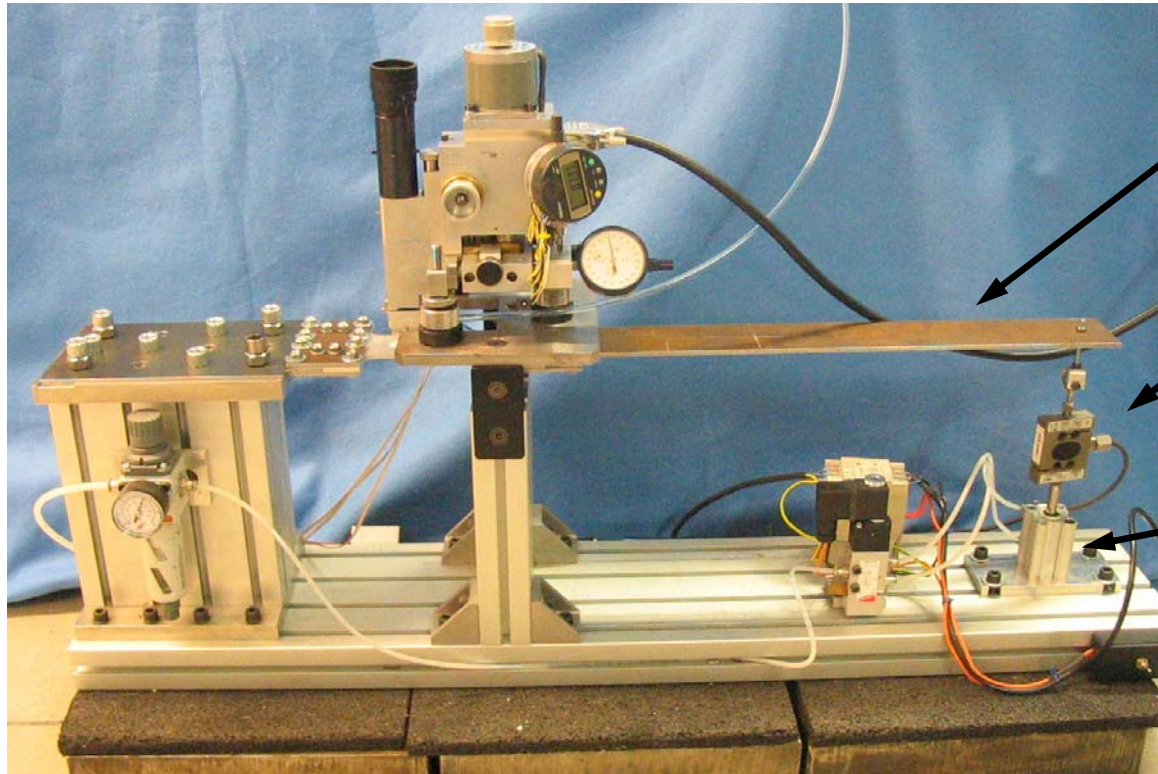


Electric step motor, to drive drilling tool depth increment

Electric contact,
between cutting tool
and specimen, to
first contact point
positioning



Bending apparatus

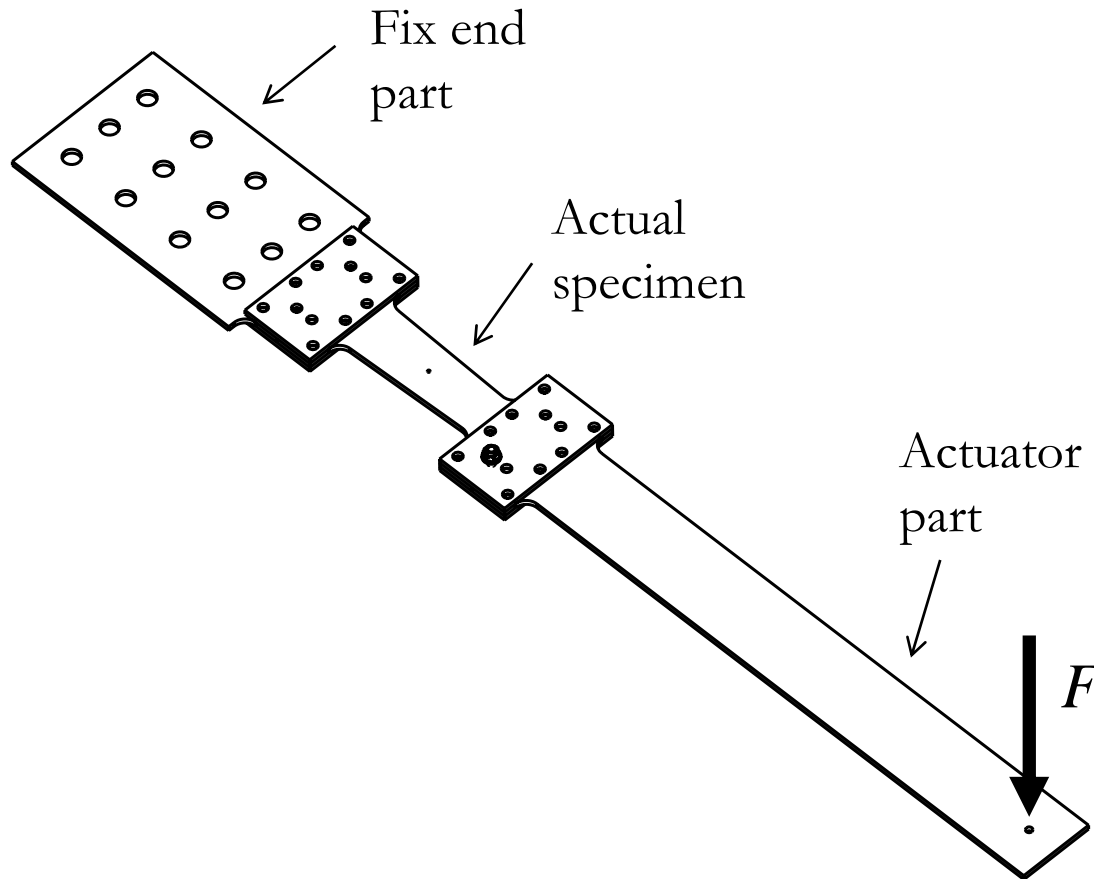


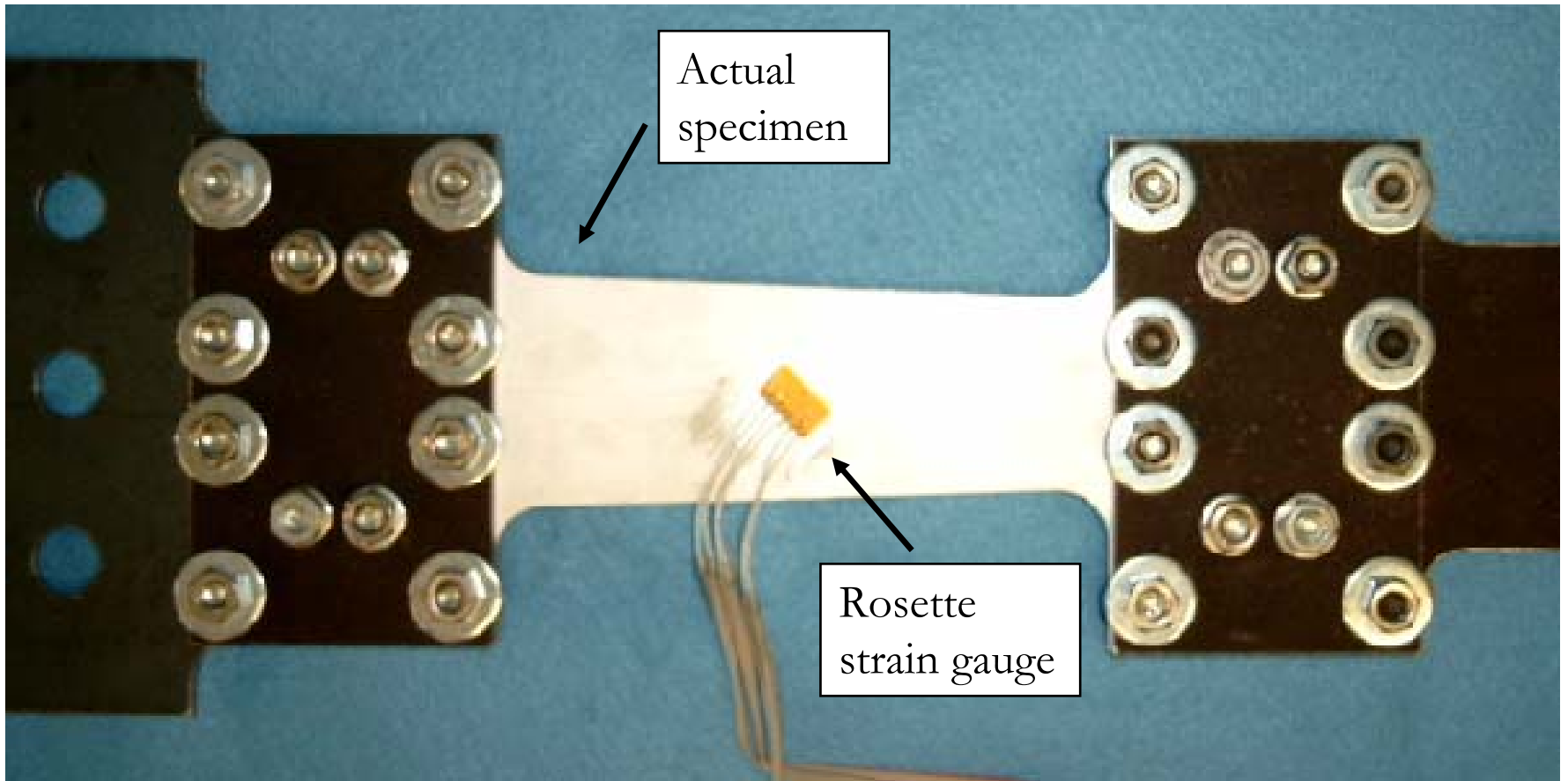
Bending specimen

Load cell

Pneumatic actuator

Bending specimen

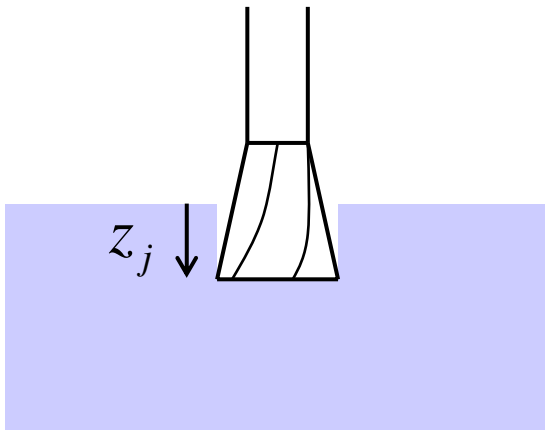




Actual
specimen

Rosette
strain gauge

Measure procedure



At each depth increment z_j

- strain recorded, **without** bending

$$\varepsilon_i^{(0)}(z_j), i = 1, 2, 3$$

- strain recorded, **with** bending

$$\varepsilon_i^{(F)}(z_j), i = 1, 2, 3$$

$$\varepsilon_i^{(0)}(0) = 0$$

Residual stress **already** embedded in the specimen
before strain gauge application

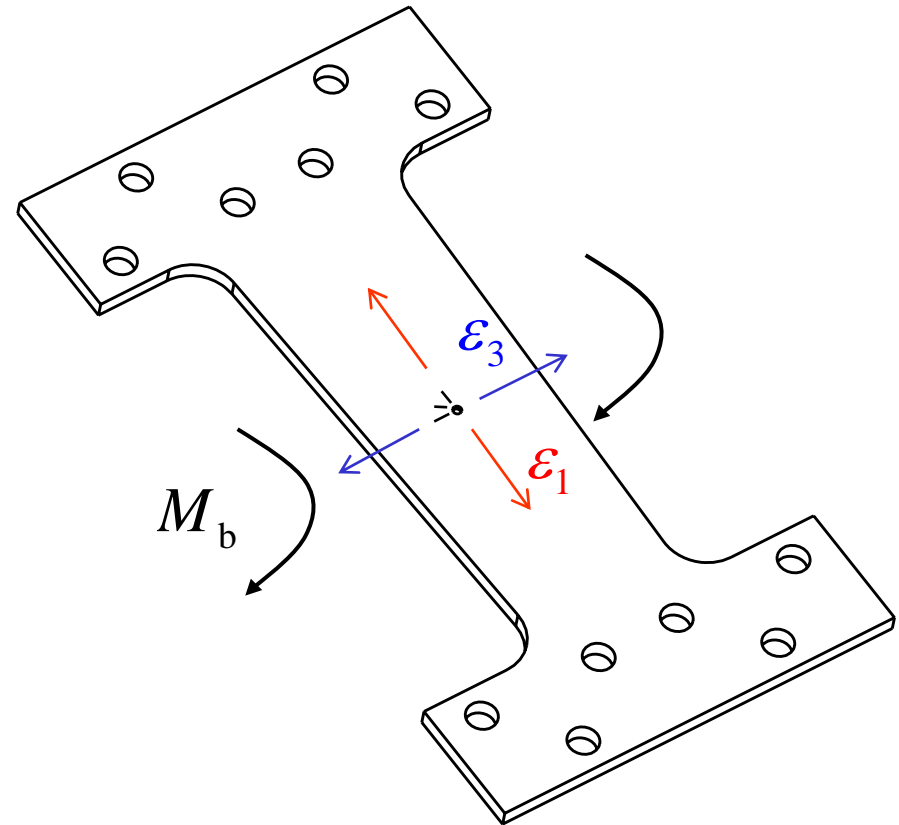
$$\varepsilon_i^{(F)}(0) \neq 0$$

Bending stress acting **after** strain gauge application

Elastic properties of material

$$\nu = -\frac{\varepsilon_3^{(F)}(0)}{\varepsilon_1^{(F)}(0)}$$

$$E = \frac{M_b}{W_b} \frac{1}{\varepsilon_1^{(F)}(0)}$$



M_b , W_b Bending moment, bending modulus,
known with good accuracy

$$\rho_i^{(\text{RS})}(z_j) = \varepsilon_i^{(0)}(z_j)$$

Relaxed strain due to **Residual Stress**

$$\rho_i^{(\text{BS+RS})}(z_j) = \varepsilon_i^{(F)}(z_j) - \varepsilon_i^{(F)}(0)$$

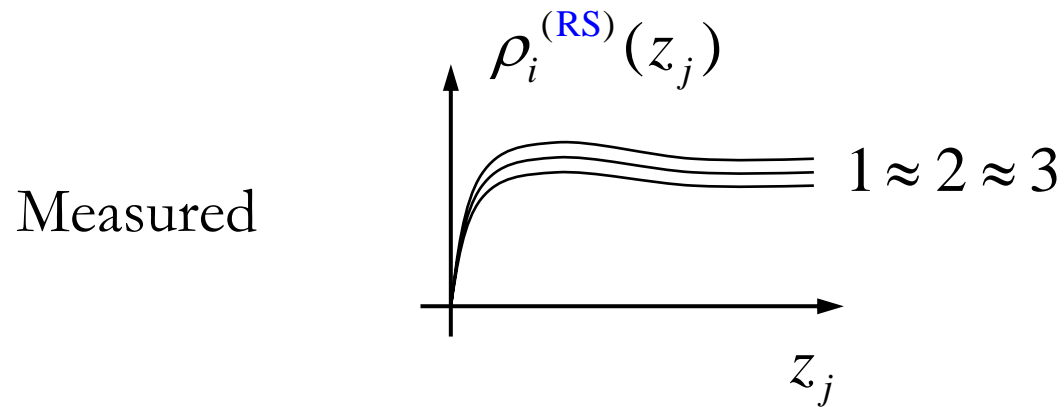
Relaxed strain due to **Bending Stress** + **Residual Stress**

$$\rho_i^{(\text{BS})}(z_j) = \rho_i^{(\text{BS+RS})}(z_j) - \rho_i^{(\text{RS})}(z_j) = \varepsilon_i^{(F)}(z_j) - \varepsilon_i^{(F)}(0) - \varepsilon_i^{(0)}(z_j)$$

Relaxed strain due to **Bending Stress** only
(decoupled from the residual stress)

$$\rho_i^{(RS)}(z_j) = \varepsilon_i^{(0)}(z_j)$$

Relaxed strain due to Residual Stress

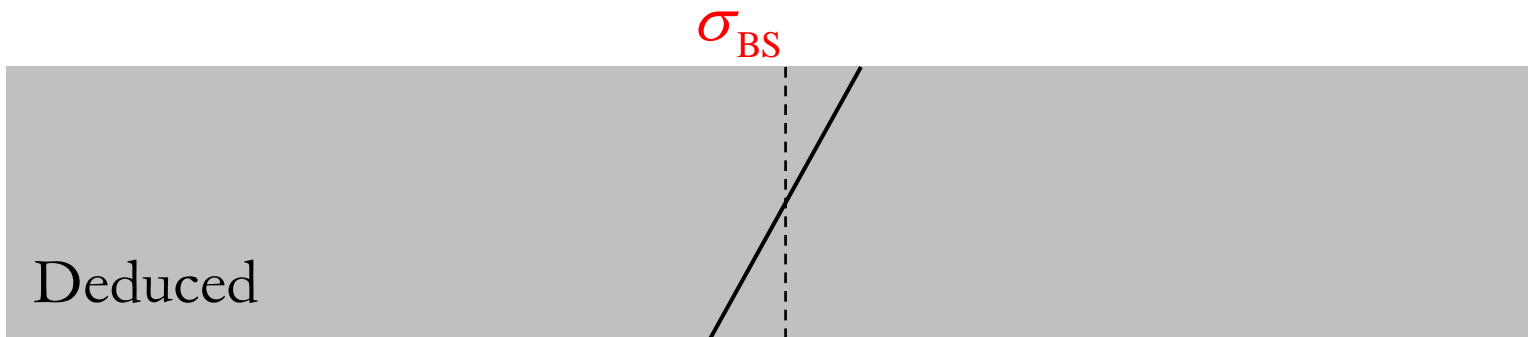
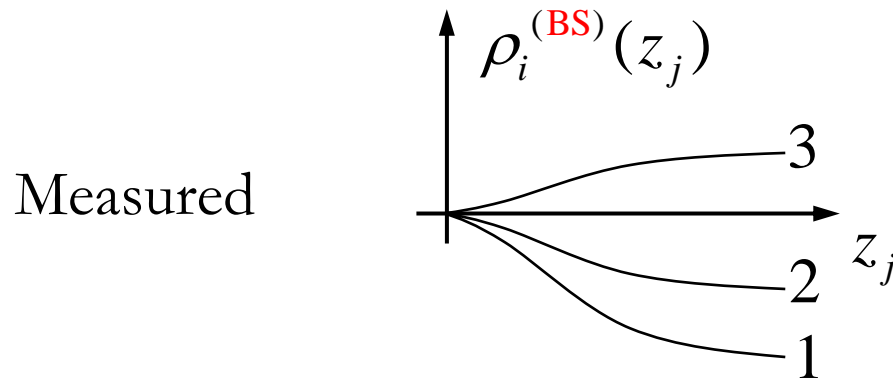


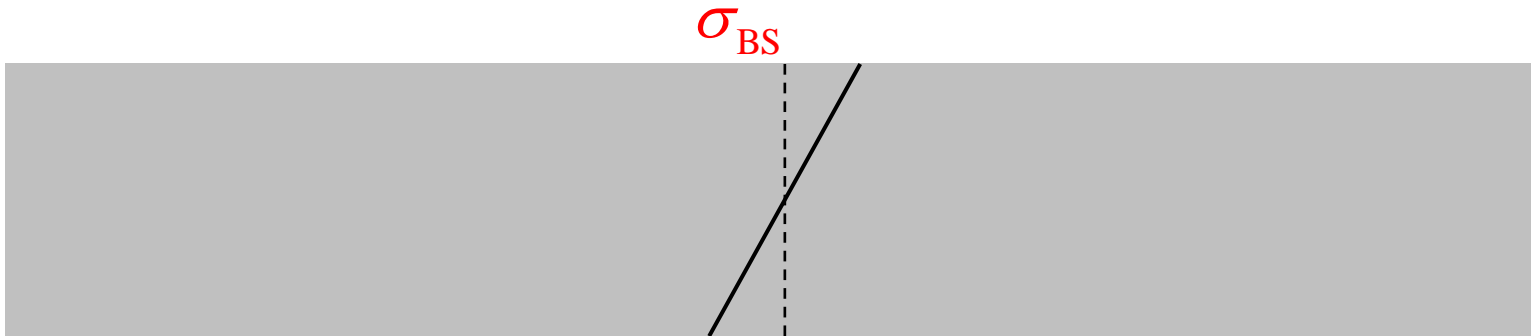
Deduced



$$\rho_i^{(\text{BS})}(z_j) = \varepsilon_i^{(F)}(z_j) - \varepsilon_i^{(F)}(0) - \varepsilon_i^{(0)}(z_j)$$

Relaxed strain due to **Bending Stress** only





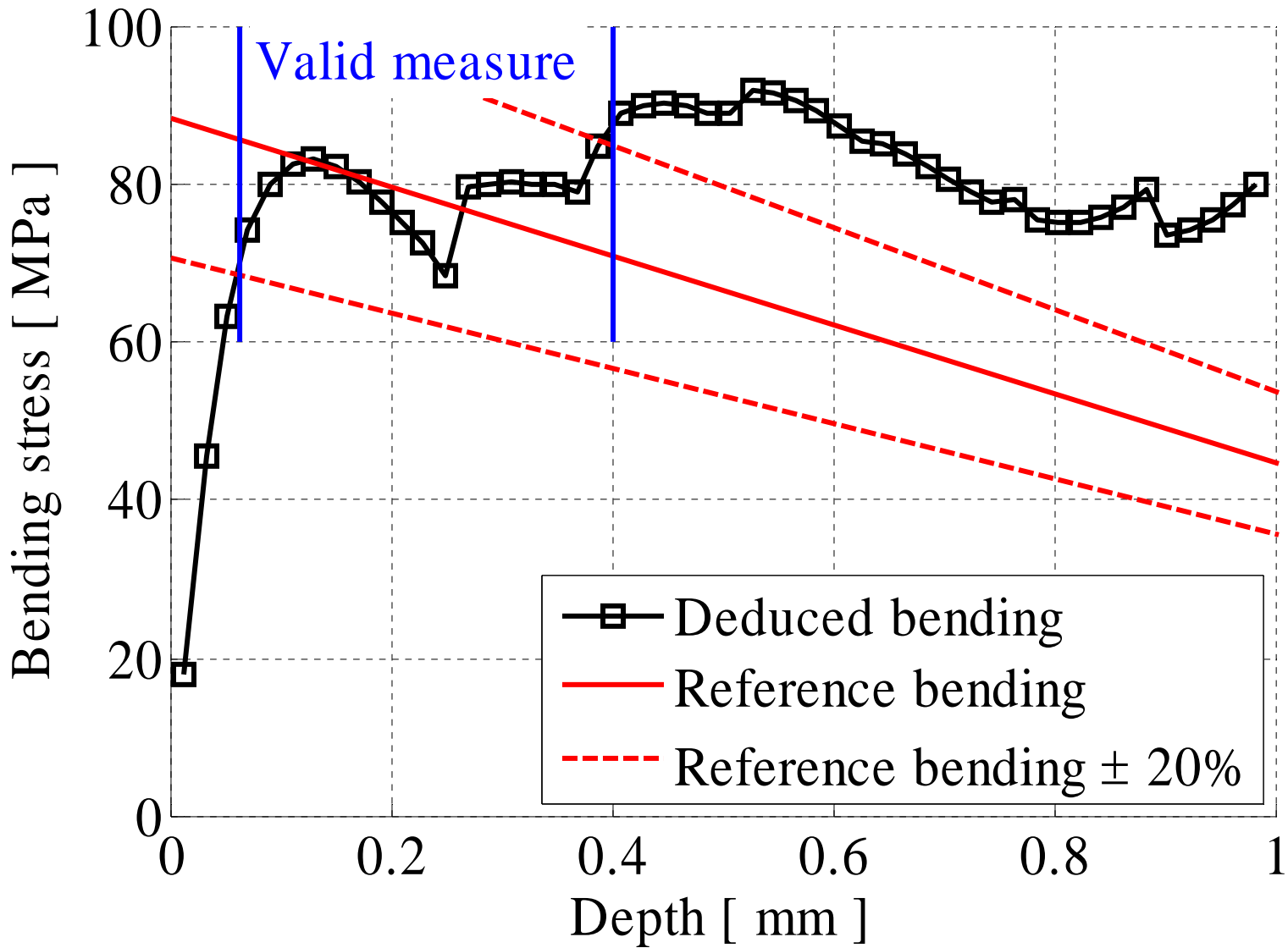
Bending Stress distribution is known with good accuracy !

Then verification can be provided

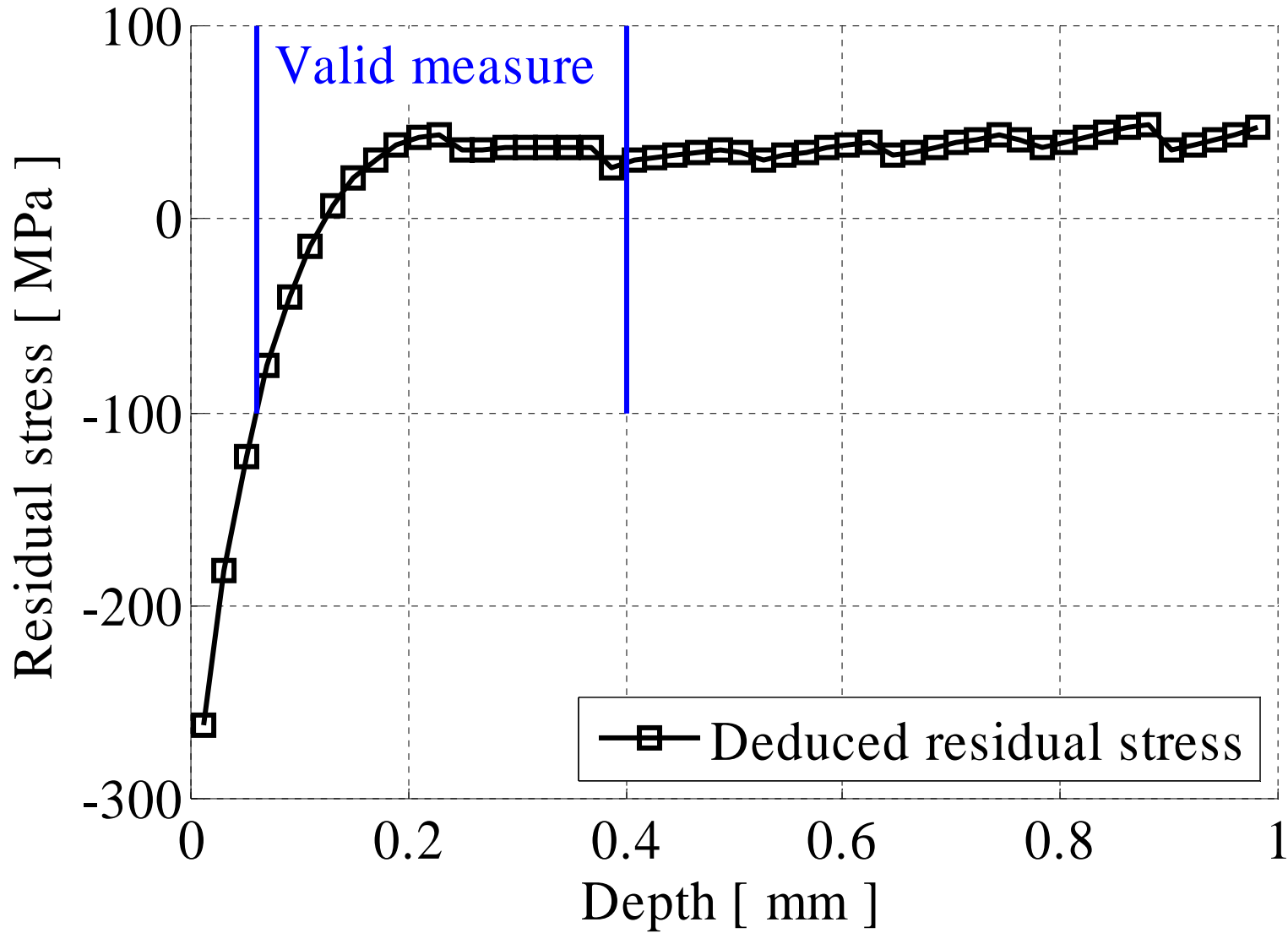
Shot peening treatments on aluminum alloy 7075-T6

	Bead size [mm]	Almen int.	Coverage
B120	0.060 – 0.125	4.5 N	100 %
Z425	0.425 – 0.600	4.5 A	100 %
B120 + Z425			

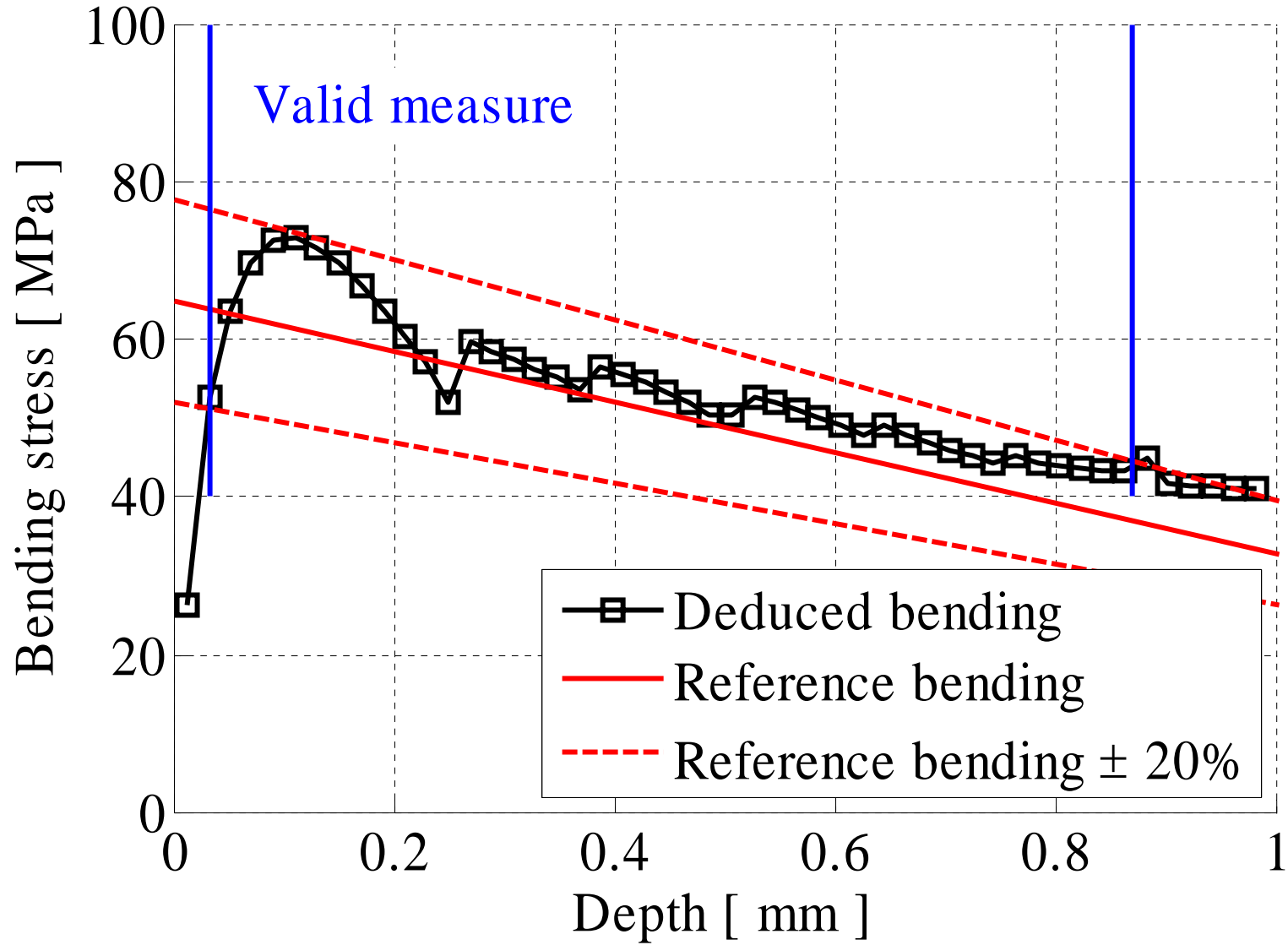
B120 – reference bending



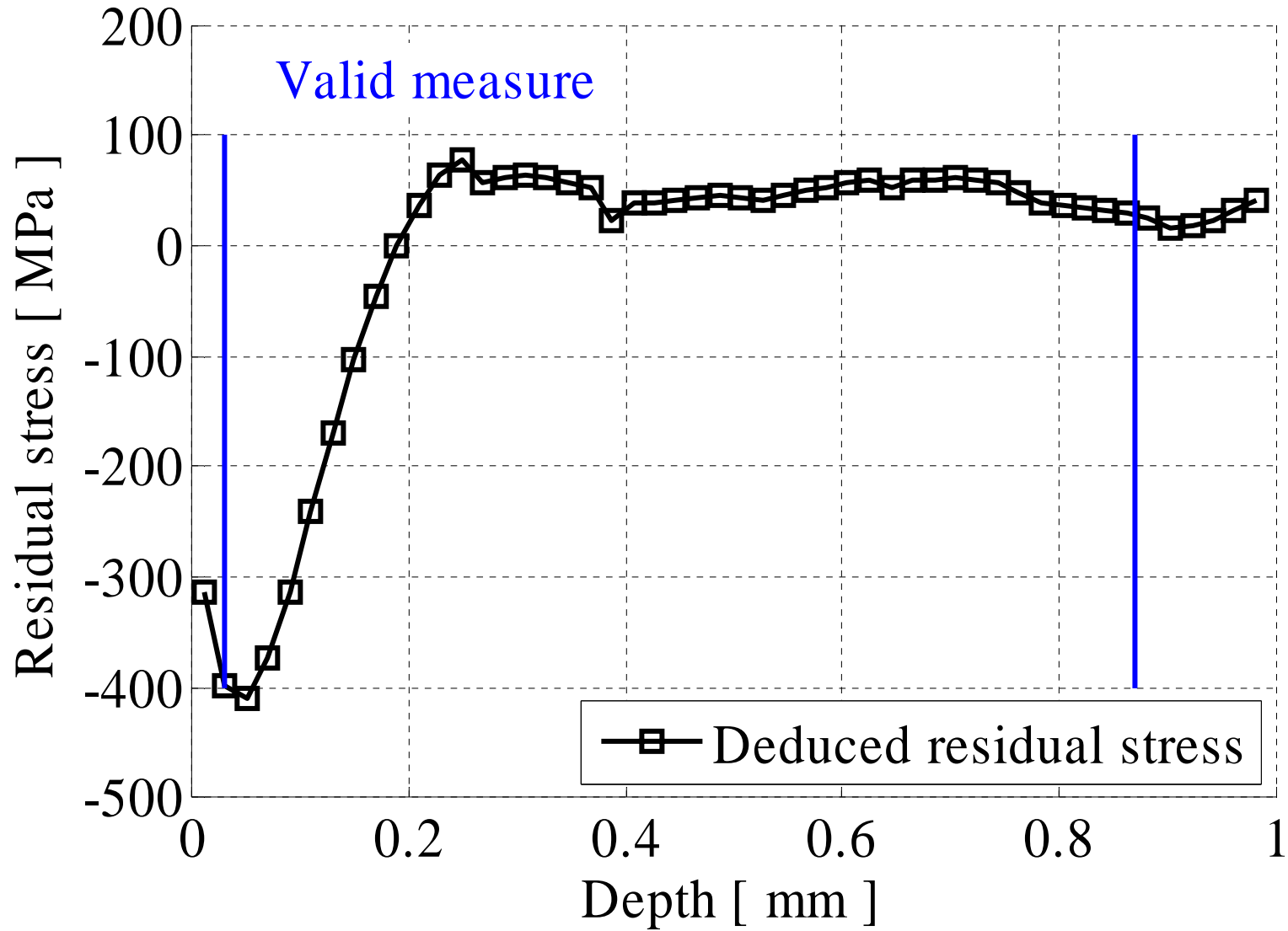
B120 – residual stress measure



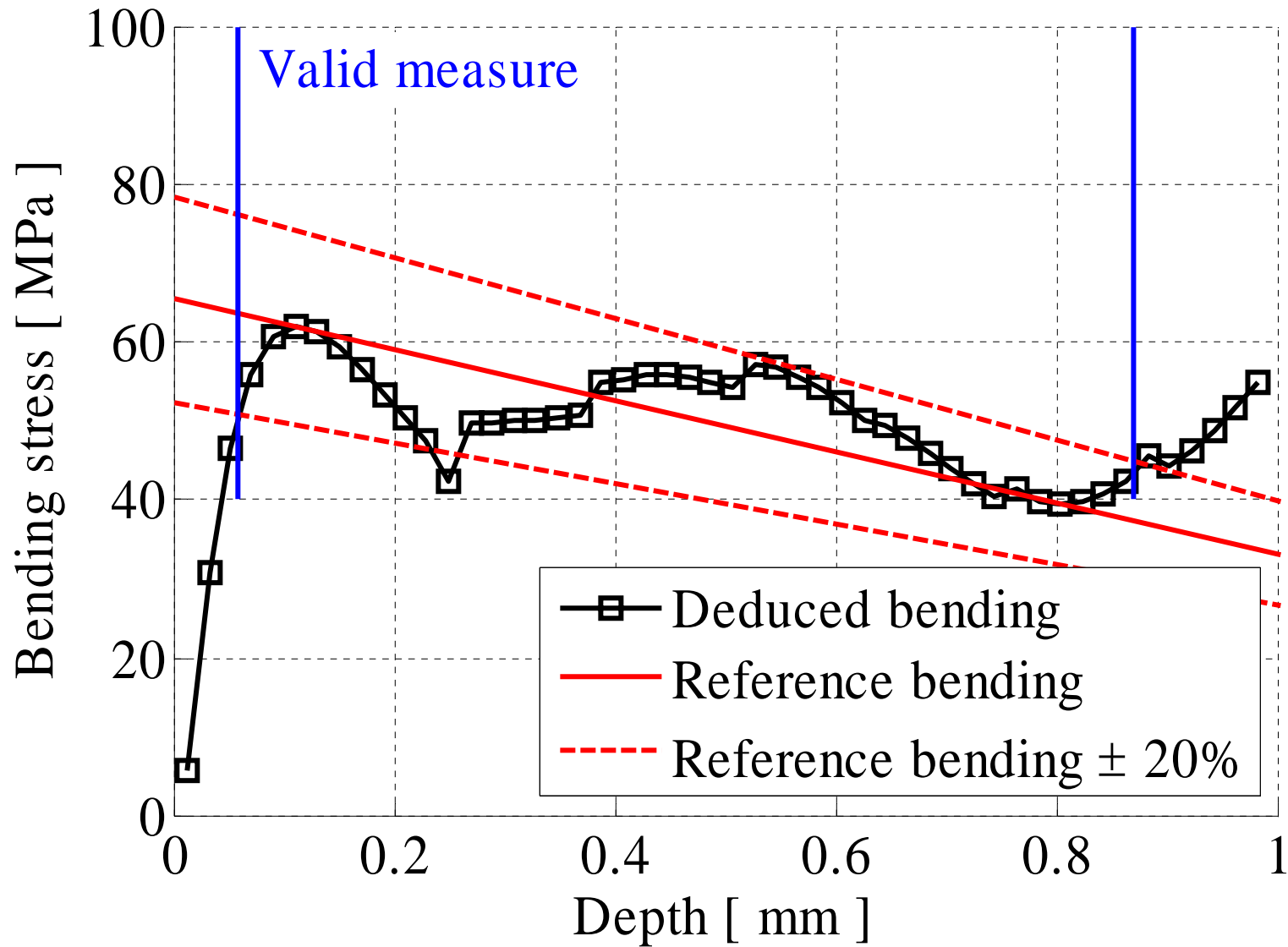
Z425 – reference bending



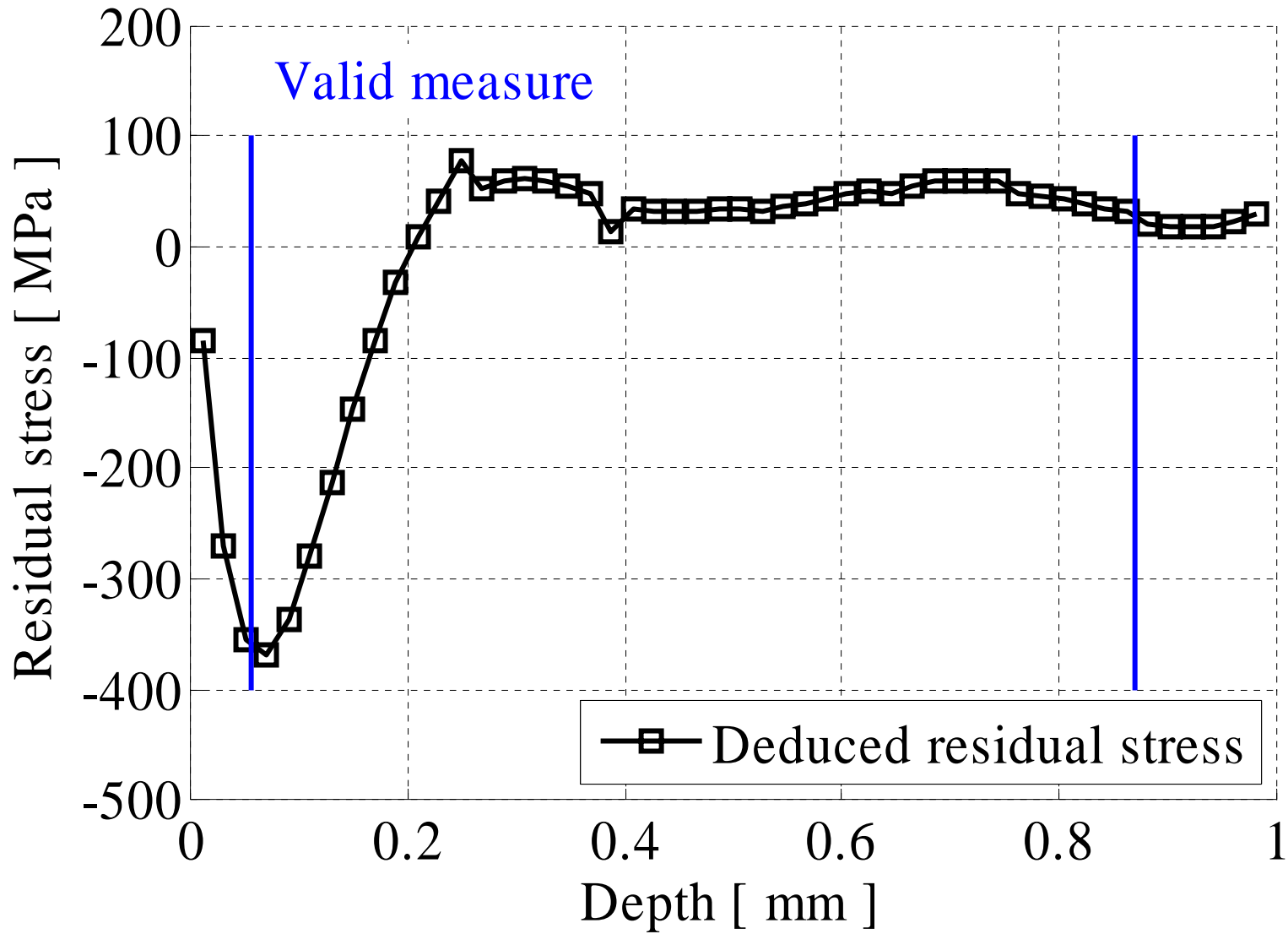
Z425 – residual stress measure



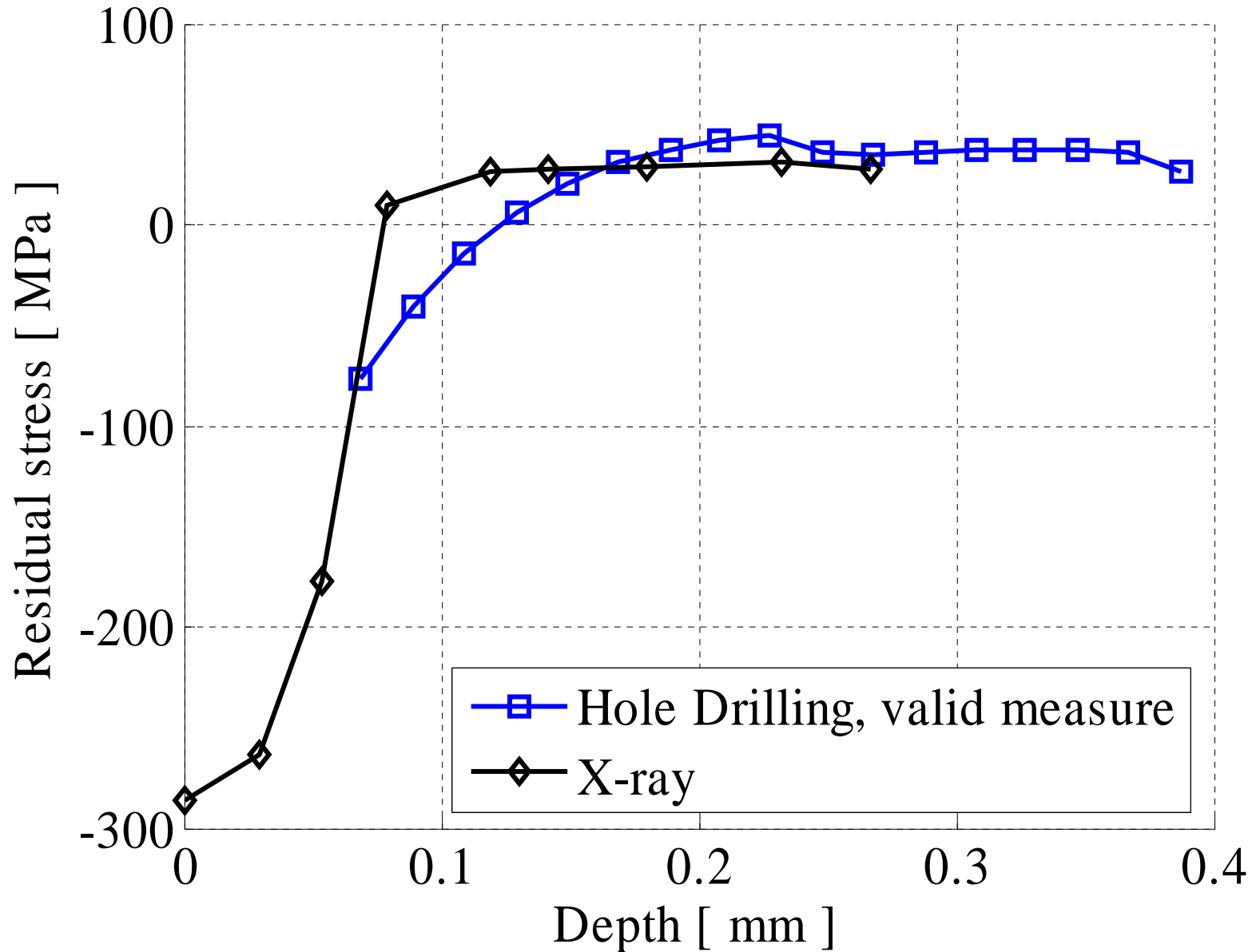
Z425B120 – reference bending



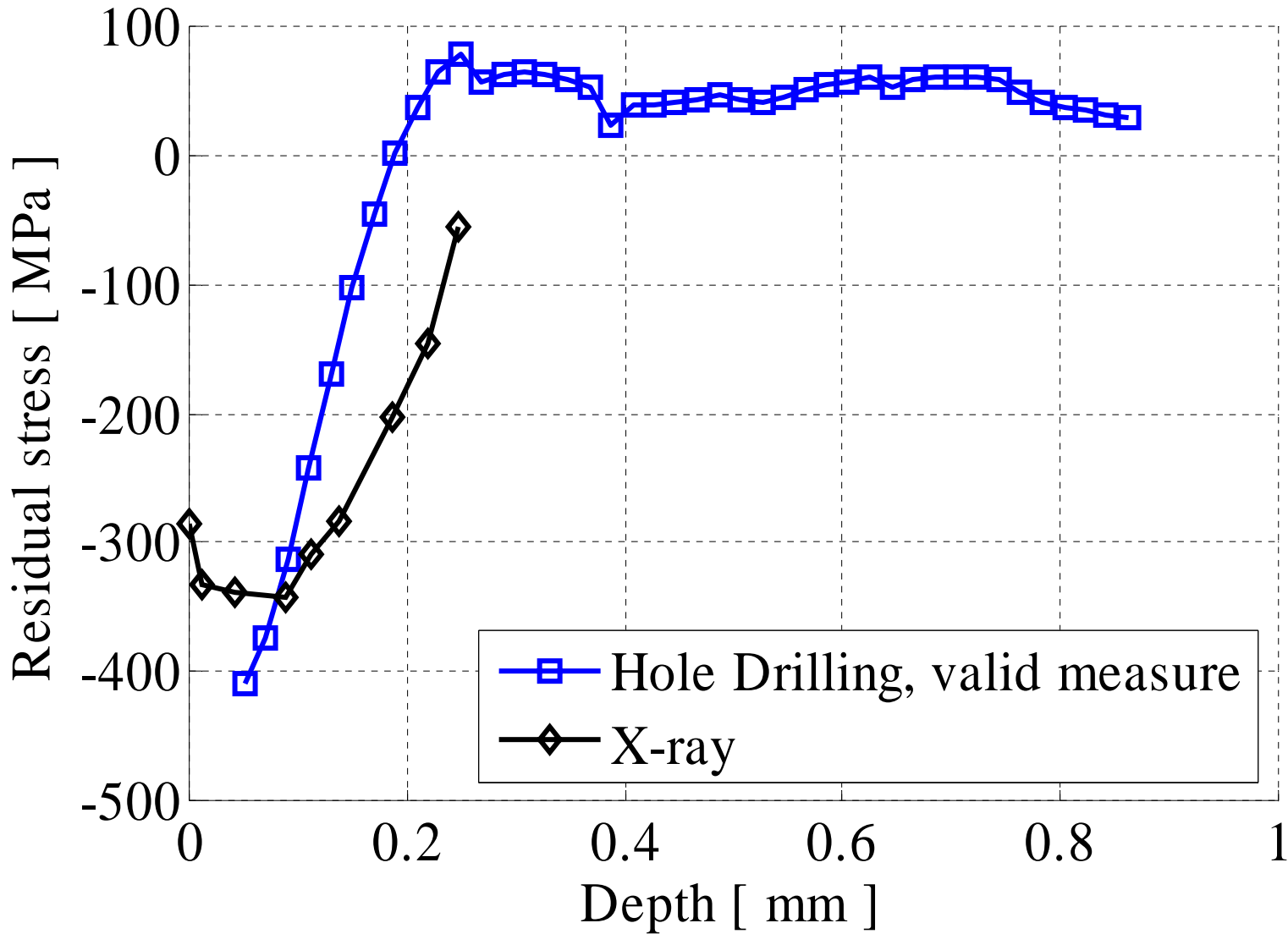
Z425B120 – residual stress measure



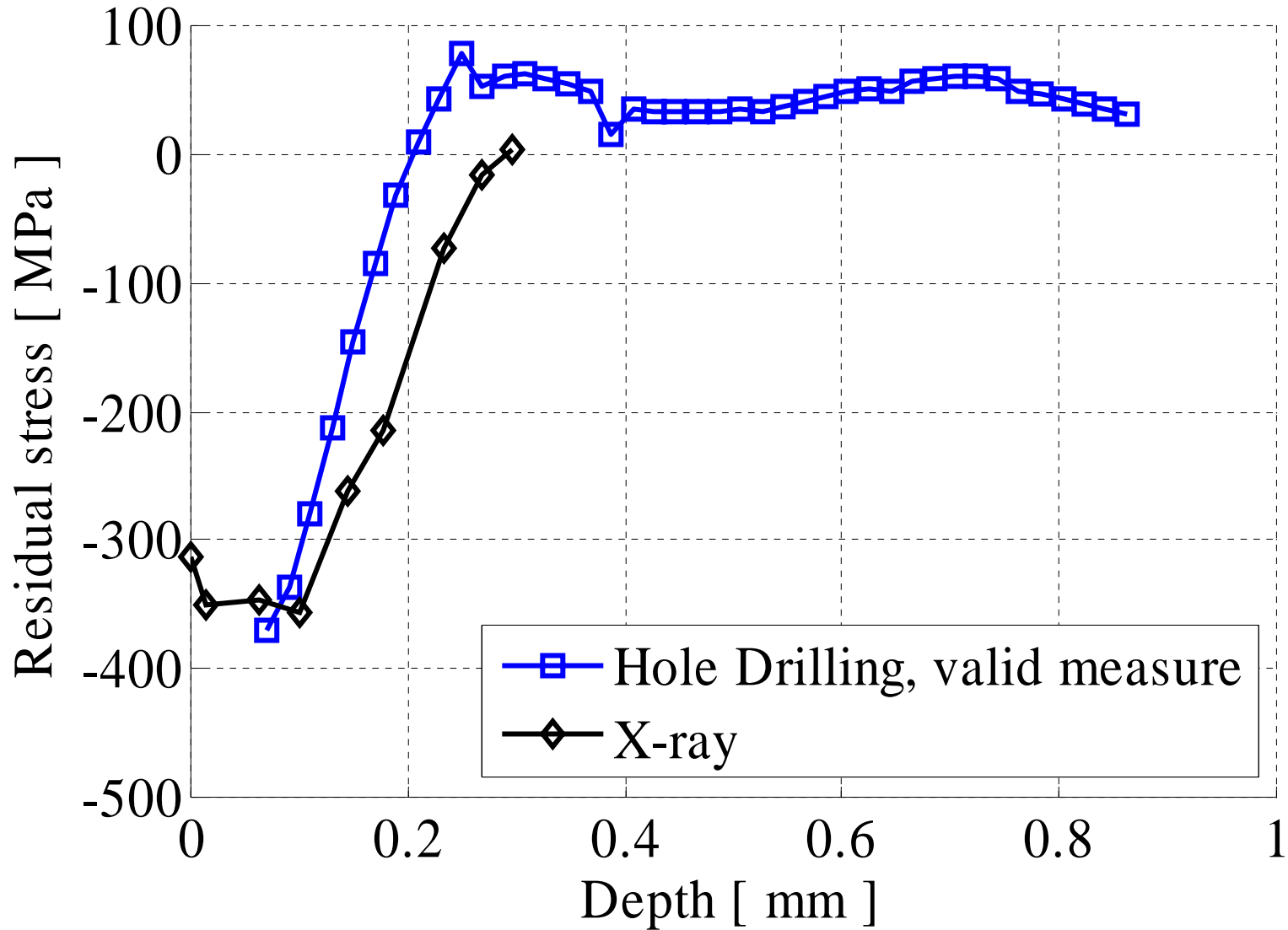
B120 – X-ray comparison



Z425 – X-ray comparison



Z425B120 – X-ray comparison



Summary & Conclusions

- Hole-drilling residual stress measure can be *verified* through a reference bending stress, with the proposed apparatus
- The measure is usually reliable, from 0.050 up to 0.800 mm with $\pm 20\%$ of accuracy (drilling tool diameter 1.6 mm)
- X-ray can measure surface residual stress, depth < 0.050 mm (expensive for larger depth)
- Deeper residual stress distribution can be measured through the Hole-drilling (cheaper for larger depth)