Nanoindenter: Anton Paar's Nano-hardness tester NHT^2

Characterization of yield criteria for zinc coated steel sheets using a Knoop nanoindenter

Tanmaya Mishra* and Matthijn de Rooij

Working principle

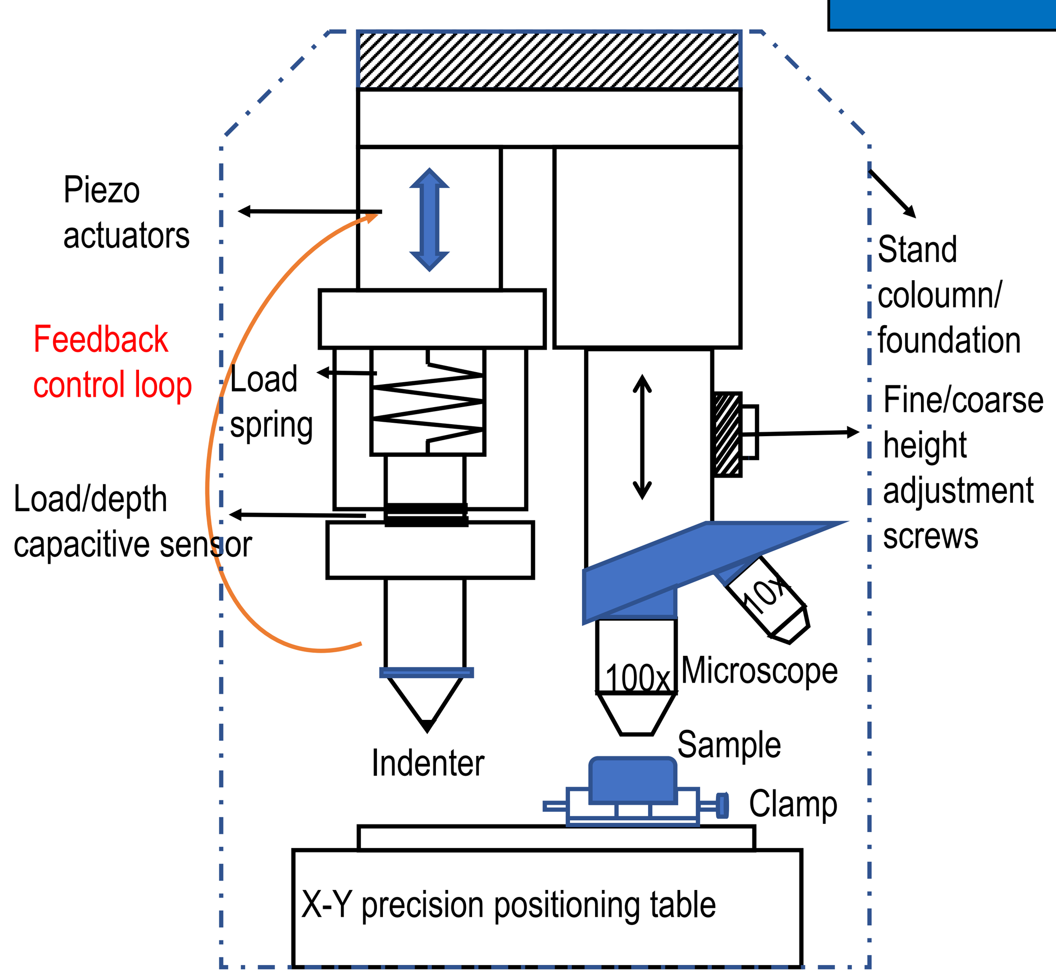

Figure 1. Schematic diagram of the Nano Indenter.

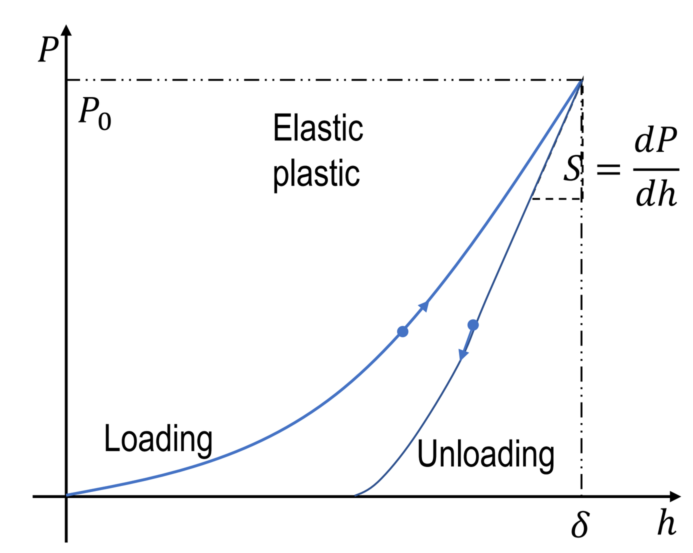

Figure 2. Depth sensing indentation.

Anton Paar's NHT^2 nanoindentation tester is designed to measure hardness, elastic modulus, creep, and other surface properties from the nanometer to the micrometer scale (see Figure 1).

- It has a normal load range from 0.1 – 500 mN.
- It has a loading rate range of 0.1 – 10 N/min.
- The penetration depth ranges are from 40 µm (fine) to 200 µm (large).

Hardness and Young's modulus of the specimen are measured using depth sending indentation (see Figure 2), based on the theory by Oliver and Pharr, 1992. Hardness is related to the maximum load P_0 and maximum penetration depth δ and the Young's modulus is related to the slope of unloading curve S.

Hardness of the specimen can also be measured from the dimensions of the indent using a microscope, given the applied load and the indenter tip geometry such as (see Figure 3a and 3b):

- Typically, a Berkovich tip is used, for thin films. It is a three-sided, geometrically self-similar pyramid.
- A Knoop indenter tip is used for measuring brittle materials and anisotropy. The geometry of this indenter is an extended pyramid with the length to width ratio being 7:1

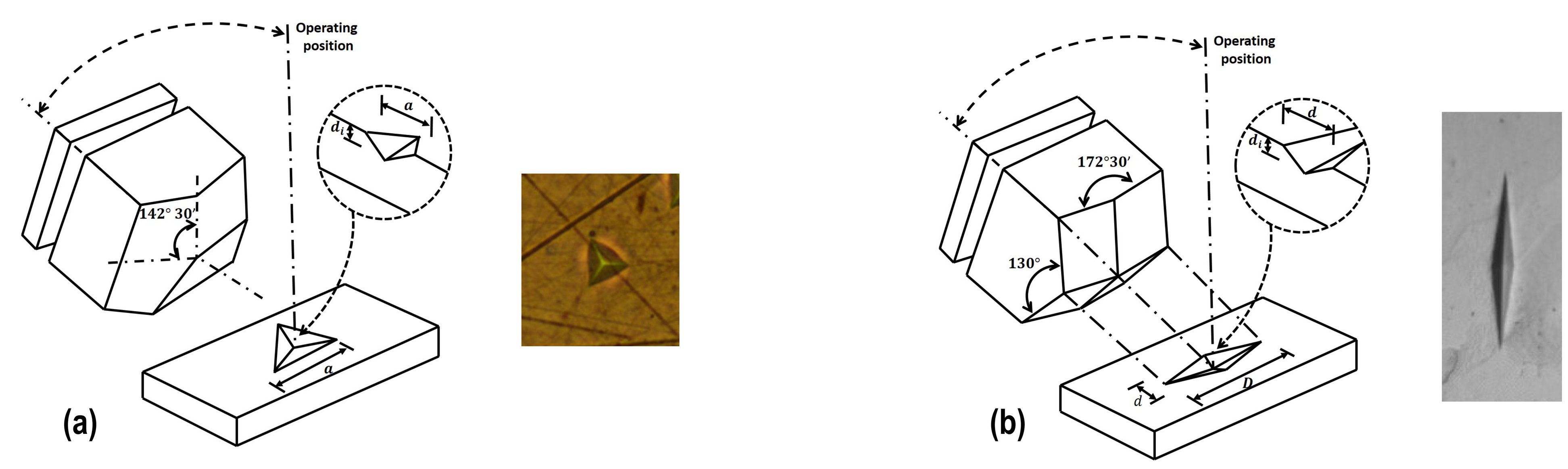

Figure 3. Schematic and images of of indenter and indent geometries (a) Berkovich indenter (b) Knoop indenter.

Results and discussion

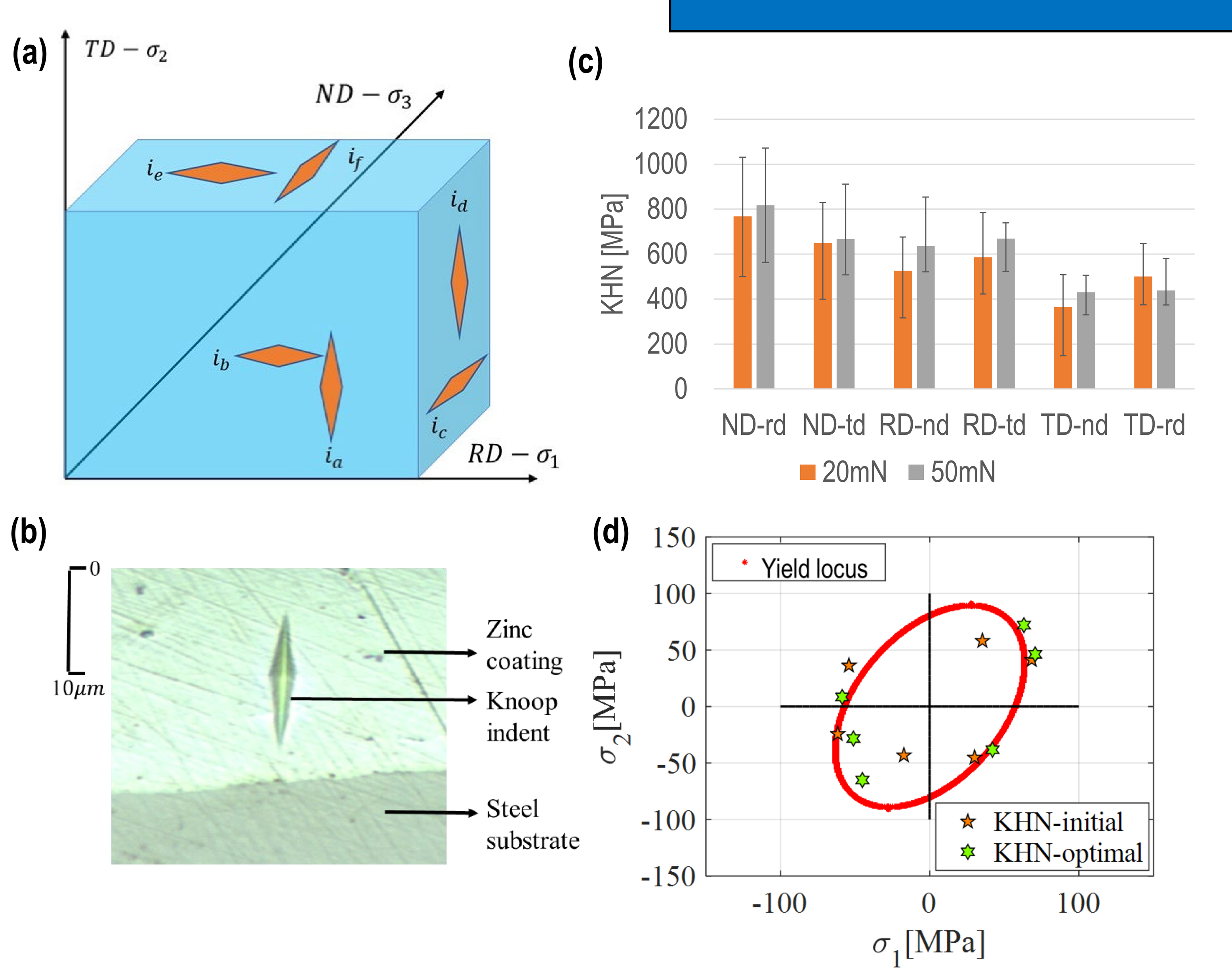

Figure 4. (a) Schematic of Knoop indentation on different cross sections of a zinc coated steel sheet with longer (in capital letters) and shorter (in small letters) diagonals of the indent along normal direction (ND/nd), rolling direction (RD/rd) and transverse direction (TD/td). (b) Knoop indent on cross-section of zinc coated steel sheet. (c) Knoop hardness number (KHN) at two indentation loads. (d) Yield locus plotted from the KHN data on the plane-stress plane.

Zinc coating on steel sheets have anisotropic yield behaviour due to the cold (texture) rolling of the galvanized steel sheets and the hexagonal structure of zinc crystals deposited on the steel substrate during galvanization.

Knoop's hardness indentations have been performed on the surface as well as on the cross sections of a zinc-coated steel sheet to obtain the corresponding Knoops hardness number (KHN) in MPa (see Figure 4a, b and c) [1].

From the KHN data and the stress ratios following the indenter's geometry, yield locus in the deviatoric plane in the rolling direction (RD) z, transverse direction (TD) θ and normal direction (ND) r is plotted. The stress ratios have been corrected for the anisotropy of the material by an optimization algorithm. Points are then plotted in the plane-stress plane using the corrected stress ratios, the strain increment vectors and indentation hardness data (see Figure 5d). The parameters for Hill's quadratic yield criteria for zinc coating are obtained from the Knoop indentation data based on a curve-fitted yield locus.

References:

[1] Mishra, T., de Rooij, M., Shisode, M., Hazrati, J., & Schipper, D. J. (2020). Characterization of yield criteria for zinc coated steel sheets using nano-indentation with knoop indenter. *Surface and Coatings Technology*, *381*, 125110.

UNIVERSITY OF TWENTE. | Surface Technology and Tribology

T. Mishra*

t.mishra@utwente.nl