A MODEL FOR SIZE-EFFECTS IN FLAT PUNCH NANOINDENTATION

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The Indentation Size Effect (ISE), that at very small scales materials are harder, has been widely reported and demonstrated through experimentation by numerous authors. One widely accepted model for explaining this effect is the Nix-Gao theory through the use of geometrically necessary dislocations (GNDs). Their model explains that the hardness for a conical indenter increases based on its indentation depth, due to the high GND density when the indentation depth is small. This model was adapted for a spherical indenter by relating the hardness effect to the contact radius of the indenter. Here we have further developed this model to explain the hardness effect for a flat punch indenter, where the GNDs are generated at the edges of the contact area and hardness increases as a function of both indenter depth and contact radius.

Our model assumes a rigid flat-punch indenter indenting into a plane strain half space. As the indenter is displaced downwards, material from the half-space is deformed at the corners in the manner described by slip line field theory. GNDs are assumed to be produced vertically below the two edges of the indenter, creating the strain hardening in ISE. The model was tested against simulations performed using the finite element modelling software Comsol over a range of scales to confirm its accuracy.

The simulation results are shown as circles in Figure 1. As expected, there is a clear positive correlation between hardness and indenter width, indicated by the line of best fit. The square data points represent the results predicted by the proposed model, which also show similar hardness results for different length scales.

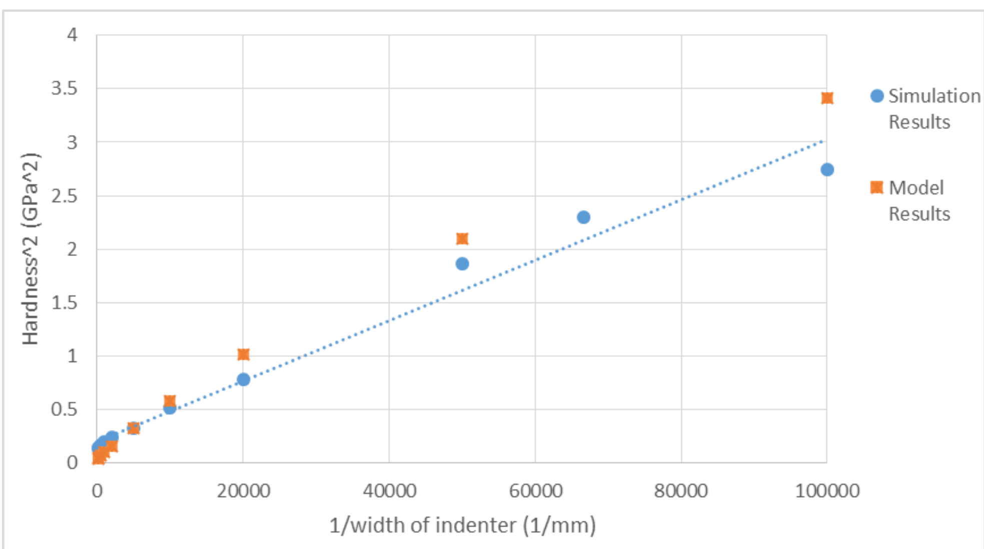

Figure 1: Comparison of analytical model with length scale plasticity simulation results