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Size effect in indentation tests: experimental and numerical investigations

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The size effect in inelastic behavior of materials is currently studied by many researchers, and indentation test is a well established tool used to investigate this phenomenon [1]. However, there is still no general agreement concerning its interpretation [2]. In the paper, we follow this line and we provide some experimental and numerical results of indentation tests performed with spherical tips of different radii. As the spherical tips are used, the stress concentration is much lower than in the case of sharp indentation, and therefore the numerical simulation of the test using complex material laws is more reliable. The indentation tests were performed on single crystal copper (in micro- and nano-scale) and the topography of residual impressions was measured. The indentation size effect is apparent: for the same relative penetration depth h/R, the slope (stiffness) of normalized loading curve increases and the normalized pile up height decreases when the tip radius decreases. Recently, a new model of gradient-enhanced plasticity of metal single crystals has been proposed [3] and applied to simulate indentation tests. The comparison of numerical and experimental results is discussed.

Fig. 1 Depth-hardness relation for fixed ratio h/R: comparison of numerical and experimental results

[1] W. D. Nix, H. Gao, Indentation size effects in crystalline materials: a law for strain gradient plasticity, J. Mech. Phys. Solids 46 (1998) 411–425.
[2] G. M. Pharr, E. G. Herbert, Y. Gao, The indentation size effect: A critical examination of experimental observations and mechanistic interpretations, Annu. Rev. Mater. Res. 40 (2010) 271–292.
[3] H. Petryk, S. Stupkiewicz, A minimal gradient-enhancement of the classical continuum theory of crystal plasticity. Part I, Part II, Arch. Mech. 68 (2016) 459-485, 487-513
[4] S. Kucharski, S. Stupkiewicz, H. Petryk, Surface pile-up patterns in indentation testing of Cu single crystals, Exp. Mech. 54 (2014) 957–969.

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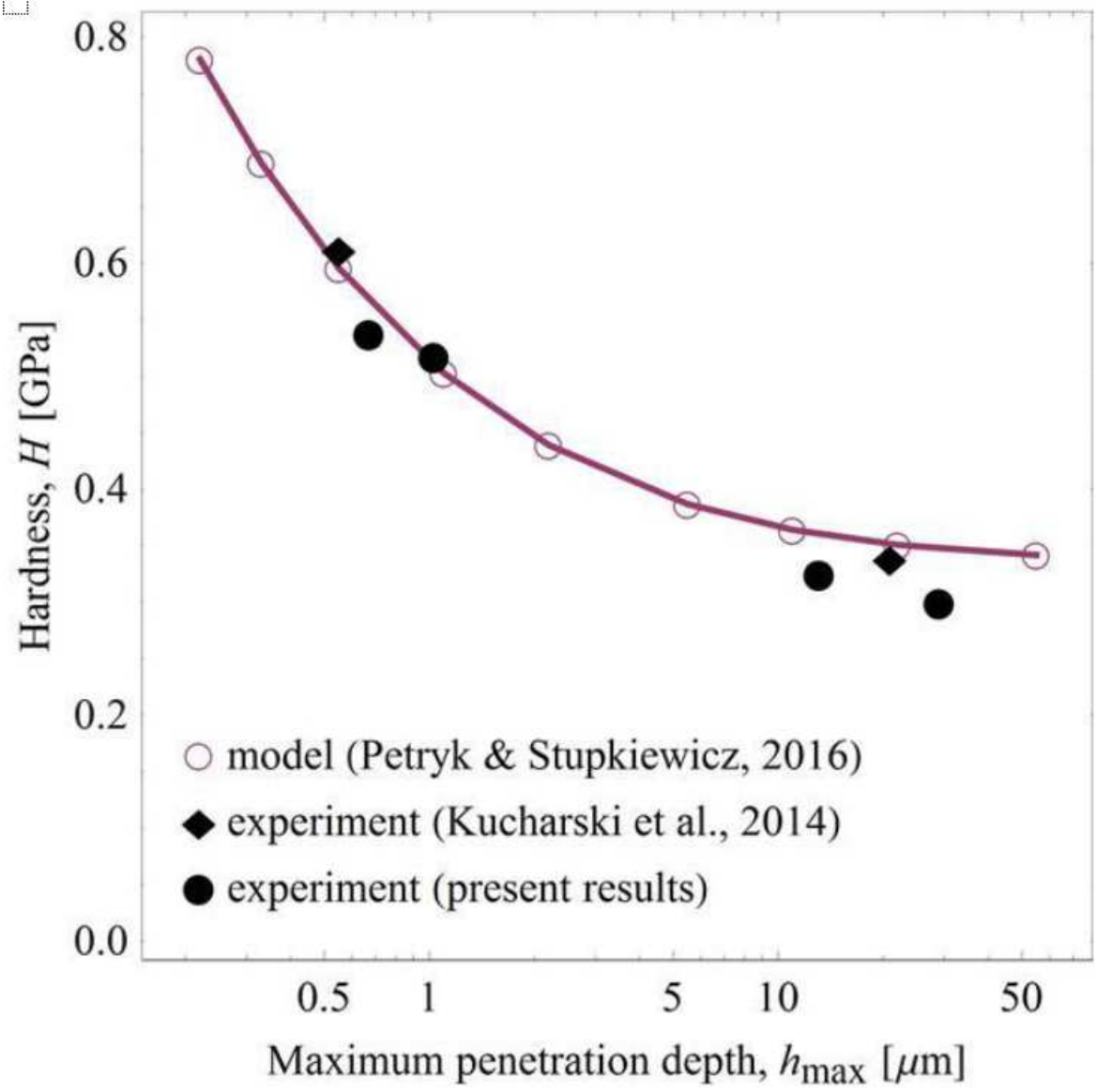

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