

“SCRATCHING THE SURFACE OF LATERAL SIZE EFFECTS (LSE): A CRITICAL COMPARISON BETWEEN INDENTATION AND SCRATCH HARDNESS SIZE EFFECTS”

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All tribological interactions have (by definition) a shear component and it is the general experience (going back to the invention of the Mohs hardness scale) that a harder material is one that is more resistant to scratch deformation. Indentation hardness is, however, more reproducible, has a smaller footprint than a scratch test, and so has become the “go to” material parameter for predicting tribological performance. This implied relationship relies on the assumption that a material's plastic properties depend only on the crystallographic direction of deformation and not on the test direction with respect to a free surface. Indentation size effects (ISE) and the realisation that material strength is genuinely length-scale dependent suggests anti-tribological wear applications. The question remains, however, as to whether further performance enhancement can be realised in practice and this requires study of scratch deformation and LSE itself.

This talk describes the efforts we have made to determine the relationship between indentation and scratch hardness and plasticity size effects. This is not a simple as it sounds and some practical reasons for this will be presented. One such issue is the presence of viscous drag in a scratch test; absent from indentation. Clear evidence of lateral (scratch) size effects, LSE, will be presented for single and poly crystal copper and directly compared to the ISE measurements made in the same samples [1,2]. Smaller scratches are harder. By scratching with a Berkovich geometry indenter it is possible to define two different scratch geometries, Edge Forward (EF) and Face Forward (FF), with the same lateral projected area. The lateral force generated for EF and FF scratches are very different. This can be correlated to the drag coefficients of the two geometries.

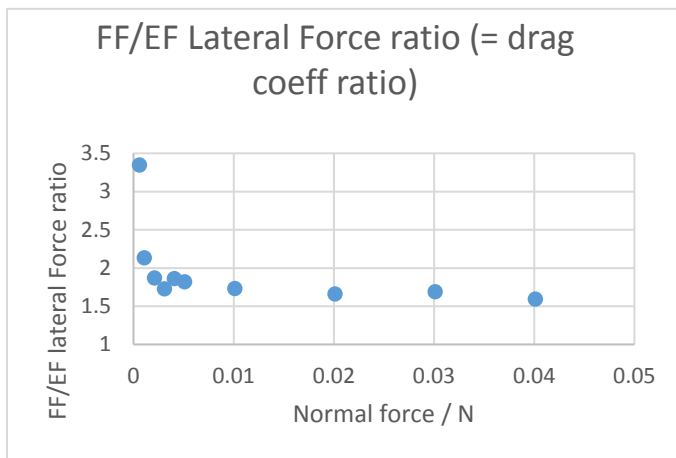


Figure 1: The ratio of drag coefficients (proportional to lateral force) has a size effect

We take the relationship developed for indentation testing that relates the hardness response to an effective length scale that is a combination of spatial frequencies due to indentation size, grain size and dislocation-dislocation interaction distance [3] and generalise it to the case of LSE. This analysis allows quantification of each length-scale in action. The results show that the ISE and LSE responses are similar but with a striking difference: the LSE response to grain size is nearly four times stronger than observed for ISE in the same Cu samples. Fascinatingly, the ratio of the EF/FF lateral force (equivalent to the ratio of drag coefficients through the sample) also shows a strong size effect as shown in figure 1.

Direct measurements of pre- and post-test grain size and plastic zone size have been performed by FIB lift out, EBSD and GND density calculations. These are presented as a direct comparison of indentation

vs. scratch deformation. Some key differences between the two deformation outcomes are revealed that are essential to the consideration of scratch and other tribological deformation, and which (in conjunction with the lateral force size effects) place a health warning on an over-reliance on indentation hardness and Hall-Petch relationships in predicting scratch and tribological performance of materials.

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