Fall 10-5-2015

Length-scale enabled quantification of surface damage by indentation: A case study separating the components of contact response due to indentation size, residual stress, and damage caused by surface machining and grinding

Nigel Jennett
Coventry University, nigel.jennett@coventry.ac.uk

Xiadong Hou
National Physical Laboratory

LENGTH-SCALE ENABLED QUANTIFICATION OF SURFACE DAMAGE BY INDENTATION: A CASE STUDY SEPARATING THE COMPONENTS OF CONTACT RESPONSE DUE TO INDENTATION SIZE, RESIDUAL STRESS, AND DAMAGE CAUSED BY SURFACE MACHINING AND GRINDING.

Nigel Jennett, Coventry University, UK
nigel.jennett@coventry.ac.uk
Xiaodong Hou, National Physical Laboratory, UK

Key Words: Residual stress, Indentation mapping, Indentation size effect

Instrumented indentation is a convenient and increasingly rapid method of high resolution mapping of surface properties. There is, however, significant untapped potential for the quantification of these properties, which is only possible by resolution of a number of serious issues that affect the absolute values for mechanical properties obtained from small indentations. The three most pressing currently are the quantification of the contributions to an indentation result due to: the Indentation Size Effect (ISE); Residual stress; and pile-up and sink-in – which is itself affected by residual stress and ISE.

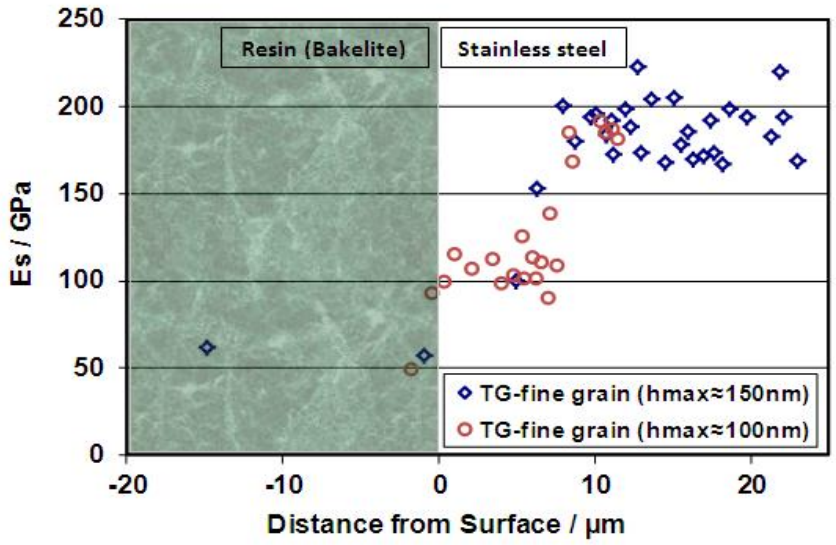

Figure 1: Indentation plane strain modulus measurement of specimen transversely ground (TG), across the deformed surface layer into Bakelite resin. Two sets of indentation data were obtained at max indentation depth set to be 150 nm and 100 nm respectively.

We take as a case study the mapping of the residual stress in a cross-section of the machined surface of a previously stress free metal. The effect of surface grinding is compared to milling and is shown to cause work hardening, an increase in residual stress, as well as surface grain size reduction. Hardness based indentation mapping is unable to distinguish these effects. However, by using Continuum based FEA models of the effect of residual stress on Modulus and an indentation modulus map, as well as a hardness map and a determination the ISE coefficient (using self-similar geometry indentation), we are able to separate out the contribution of stress and pile up, indentation size effect, leaving a quantified measurement of the effect of surface treatment on grain size and dislocation density. Since the FEA results can be expressed in parameterised form for general application, this provides an accessible method for improved mechanical property and surface stress mapping.