MEASUREMENT OF HARDNESS AND ELASTIC MODULUS BY DEPTH SENSING INDENTATION: FURTHER ADVANCES IN UNDERSTANDING AND REFINEMENTS IN METHODOLOGY

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Depth sensing indentation technique has been widely used to measure small scale mechanical properties over the years. Starting from the seminal work of Oliver & Pharr [1], there have been many improvements / modifications to the test methodology and also significant advances in measurement electronics / testing instrumentation. These advancements provide opportunities to not only develop novel testing capabilities but also further improve the precision and accuracy of the most common measurement parameters – hardness and elastic modulus.

In this regard, this work presents a comprehensive study on the various steps involved in a typical depth sensing indentation test, viz., surface approach, surface detection, load-time history including superimposing an oscillatory force on broad band load, unloading and drift rate measurement. The effect of each of these steps on the accuracy and precision of the hardness and elastic modulus measurement will be discussed with specific focus on frequency specific testing techniques such as continuous stiffness measurement. The effect of the instrument's measurement time constants and dynamic parameters such as mass, spring constant and damping coefficient during different steps of an indentation test and thereby on the hardness and elastic modulus will be presented. A simple model is developed to simulate a depth sensing indentation test that incorporates the material and instrumentation parameters to help visualize the overall process and provide new insights for pushing the limits of the currently available instrumentation for improved precision and accuracy. This involves performing tests beyond the traditional boundaries of parameter space such as increased oscillation amplitude, strain rate, oscillation frequency, etc. For instance, if the indentation strain rate gets high compared to the oscillation frequency, inaccuracies can occur. This work presents the critical experimental parameters and the associated first order corrections for the potential errors. The model predictions and corrections are validated on different classes of materials. Finally, guidelines for measuring hardness and elastic modulus using a depth sensing indentation test with significantly improved precision and accuracy within the limitations of the currently available instrumentation will be discussed.

[1] Oliver & Pharr, Journal of Materials Research, 7(6),1992.