

# INFLUENCE OF MODULUS-TO-HARDNESS RATIO AND HARMONIC PARAMETERS ON CONTINUOUS STIFFNESS MEASUREMENT DURING NANOINDENTATION

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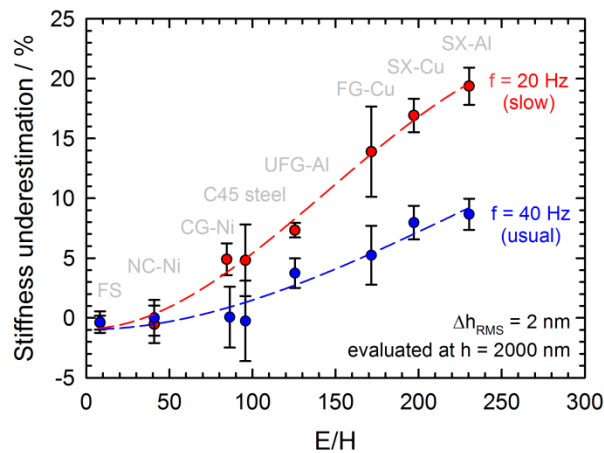
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Dynamic nanoindentation is a popular method for continuously probing the mechanical properties of a sample as a function of depth. Its operation principle and main applications will be reviewed at first. Then, it will be shown that special caution should be exercised when testing materials with high modulus-to-hardness ratios ( $E/H$ ) at fast loading rates, as the choice of harmonic parameters can result in a significant underestimation of the contact stiffness and hence the elastic modulus.

The errors are caused by the processing of elastic-plastic data by the lock-in amplifier in a technique initially designed to be applied to elastic deformation only. Intuitively, the higher the amount of plastic deformation within a cycle is, the larger the difference to the ideal condition is, and the higher the bias is. In detail, the largest deviations are observed for both high  $E/H$  and  $\dot{P}/(\Delta P \cdot f)$  ratios, evidencing that both the sample properties and the selected testing parameters play a role. The exact mechanisms leading to this bias will be discussed from simulated CSM signals and experimental measurements confirming these trends will be shown.

The possible consequences of flawed measurements will be highlighted and a practical method for detecting possible occurrence from the phase angle signal will be presented.



Stiffness deviation observed for different materials during dynamic nanoindentation at  $h=2000$  nm with standard testing parameters.

[1] Merle, B., Maier-Kiener, V., Pharr G.M. Influence of modulus-to-hardness ratio and harmonic parameters on continuous stiffness measurement during nanoindentation. Acta Materialia 134C (2017) pp. 167-176