Evaluation of Analysis Methods for High Strain Rate Nanoindentation

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PAYWALLED ARTICLE

Hello {{lead.First Name:default=researcher}},

For this month's **Nanomechanical Testing Journal Club**, I am happy to share the research article "**Evaluation of Analysis Methods for High Strain Rate Nanoindentation**" published in *JOM*. This paper evaluates analysis methods for extracting mechanical properties from high strain rate nanoindentation.

Background

High strain rate nanoindetnation is increasingly important for understanding material behavior under dynamic conditions such as impact or high-speed deformation in aerospace and automotive applications. While conventional nanoindentation operates at quasi-static strain rates, extending the technique to high strain rates introduces challenges related to instrument dynamics, data interpretation, and appropriate analytical assumptions.

Nanoimpact testing achieves very high strain rates through probe acceleration but produces variable strain rates during impact whereas constant strain rate indentation maintains a controlled strain rate history and enables more direct correlation between deformation mechanisms and strain rate. This study focuses on the latter approach, which is better suited for systematic analysis and applications.

Testing Assumptions

At high strain rate, conventional Oliver–Pharr analysis becomes less applicable due to limitations in continuously determining contact stiffness. Therefore, two alternative assumptions are evaluated:

- Constant contact depth-to-displacement ratio (h_c/h)
- Constant reduced modulus (E_r)

The validity of these assumptions was first tested using quasi-static nanoindentation on fused quartz and tungsten. Results showed that h_c/h is not constant, varying with indentation depth and temperature, particularly increasing with temperature in tungsten due to enhanced plasticity. In contrast, reduced modulus remains largely constant with depth, showing only minor variation with temperature.

Despite the violation of the constant h_c/h assumption, both methods were applied to high strain rate nanoindentation experiments on tungsten across strain rates from 1 to 1000 s^{-1} and temperatures up to 300°C. Hardness trends obtained from both methods were similar, though the h_c/h-based method produced slightly higher absolute values (~0.25 GPa difference). Importantly, both methods showed consistent trends: hardness increases with strain rate and decreases with depth due to the indentation size effect.

Calculating Strain Rate Sensitivity

The key outcome is that both analysis methods produce comparable strain rate sensitivity (m), a critical parameter describing how strength varies with strain rate. For example, tungsten exhibited an $m \approx 0.055$ at 250°C, increasing with temperature. Differences between the two methods were within experimental uncertainty, and results aligned well with previous nanoindentation and literature data.

In conclusion, although both approaches have their own limitations, each method provides a practical and reliable way to determine derived properties, particularly strain-rate sensitivity. This study emphasizes that careful implementation and methodological consistency are more critical than strict adherence to theoretical assumptions, especially when the focus is on relative trends rather than absolute property values.

I highly recommend this paper to researchers working on high strain-rate nanoindentation experiments. Please **contact me** if you need any assistance with your nanomechanical testing applications.

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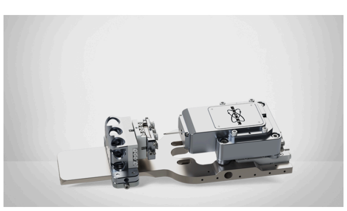

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