CYCLICAL NANOINDENTATION STRESS-STRAIN MEASUREMENT

Prepared by
Jonathan Thomas and Pierre Leroux

Introduction

Continuous stiffness measurements (CSM) obtained by nanoindentation reveals the stress-strain relationship of materials with minimally invasive methods. Unlike traditional tensile testing methods, nanoindentation provides stress-strain data at the nanoscale without the need of a large instrument. The stress-strain curve provides crucial information on the threshold between elastic and plastic behavior as the sample is subject to increasing loads. CSM gives the capability to determine the yield stress of a material without dangerous equipment.

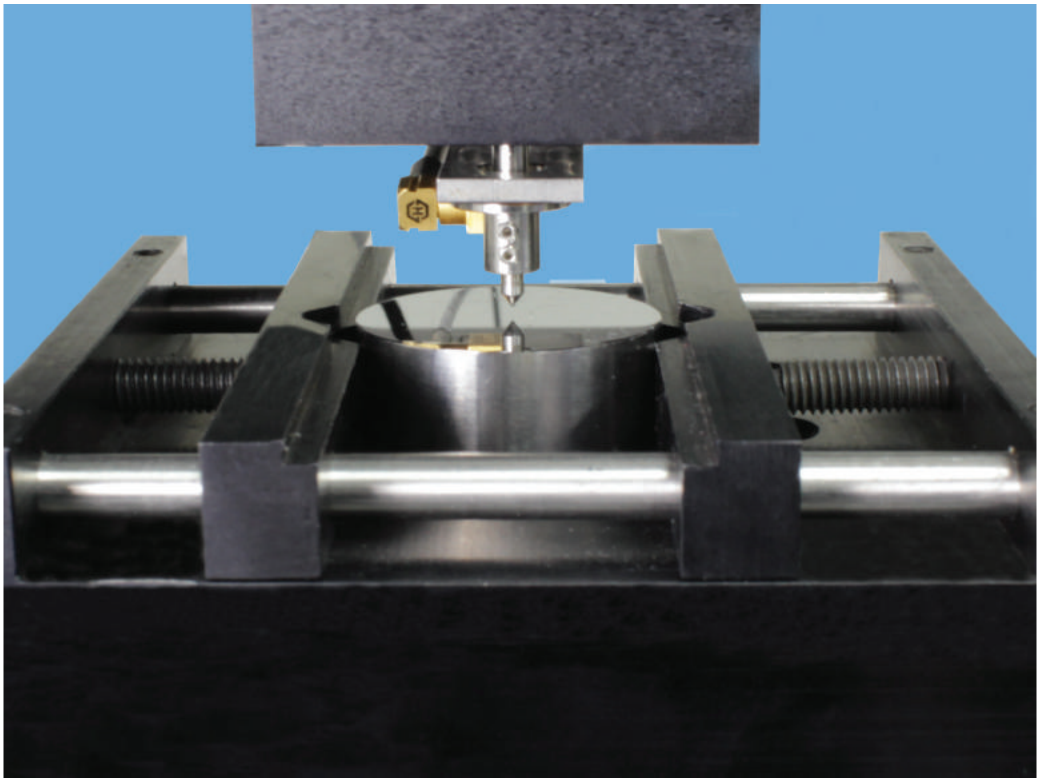
Importance of Nanoindentation

Nanoindentation provides a reliable and user-friendly method to quickly investigate stress-strain data. Furthermore, measuring stress-strain behavior on the nanoscale makes it possible to study important properties on small coatings and particles in materials as they get more advanced. Nanoindentation provides information on elastic limit and yield strength in addition to hardness, elastic modulus, creep, fracture toughness, etc. making it a versatile metrology instrument.

The stress-strain data provided by nanoindentation in this study identifies the elastic limit of the material while only going 1.2 microns into the surface. We use CSM to determine how mechanical properties of materials develop as an indenter travels deeper into the surface. This is especially useful in thin film applications where properties can be depth dependent. Nanoindentation is a minimally invasive method of confirming material properties in test samples.

MEASUREMENT OBJECTIVE

In this application, the Nanovea mechanical tester uses CSM to study hardness and elastic modulus versus depth and stress-strain data on a standard steel sample. Steel was chosen for its commonly recognized characteristics to display the control and accuracy of the nanoscale stress-strain data. A spherical tip with a 5-micron radius was used to reach high enough stresses beyond the elastic limit for steel.



Sample tested on Nanovea Mechanical Tester.

TEST PROCEDURE

The following indentation parameters were used:

Parameters	
Maximum force (mN)	300
Loading Rate (mN/min)	150
Unloading rate (mN/min)	600
Creep (Sec)	0
Computation Method	ASTM E-2546 & Martens Hardness
Indenter Type	5-micron Spherical tip
Amplitude (mN)	2
Frequency	10 Hz

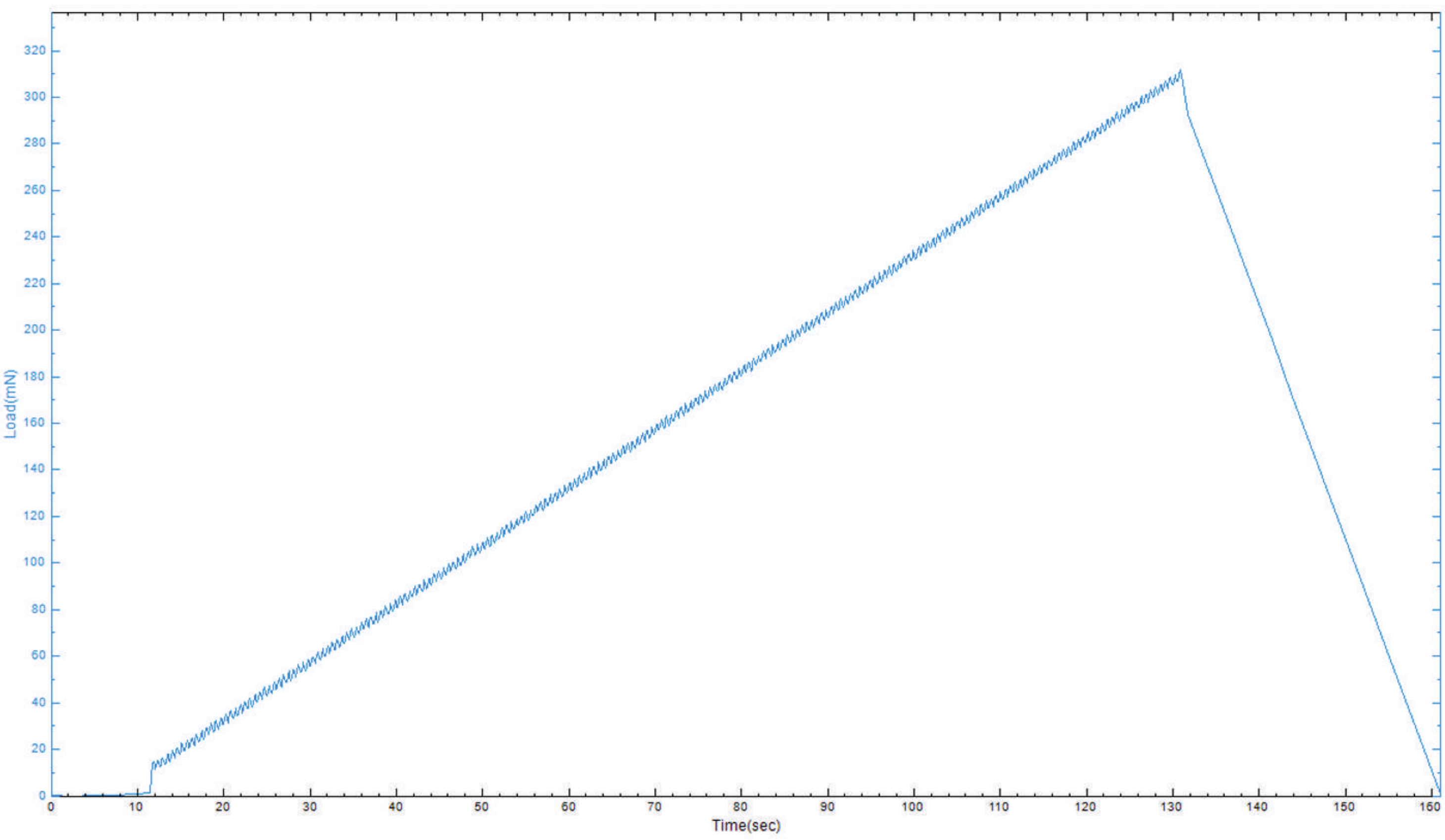


Figure 1: Load profile over time applied for this test.
Between 10 and 130 seconds the oscillations are applied during loading.

RESULTS AND DISCUSSION

Increase in load during oscillations provide the following depth versus load curve. Over 100 oscillations were conducted during loading to find the stress-strain data as the indenter penetrates the material.

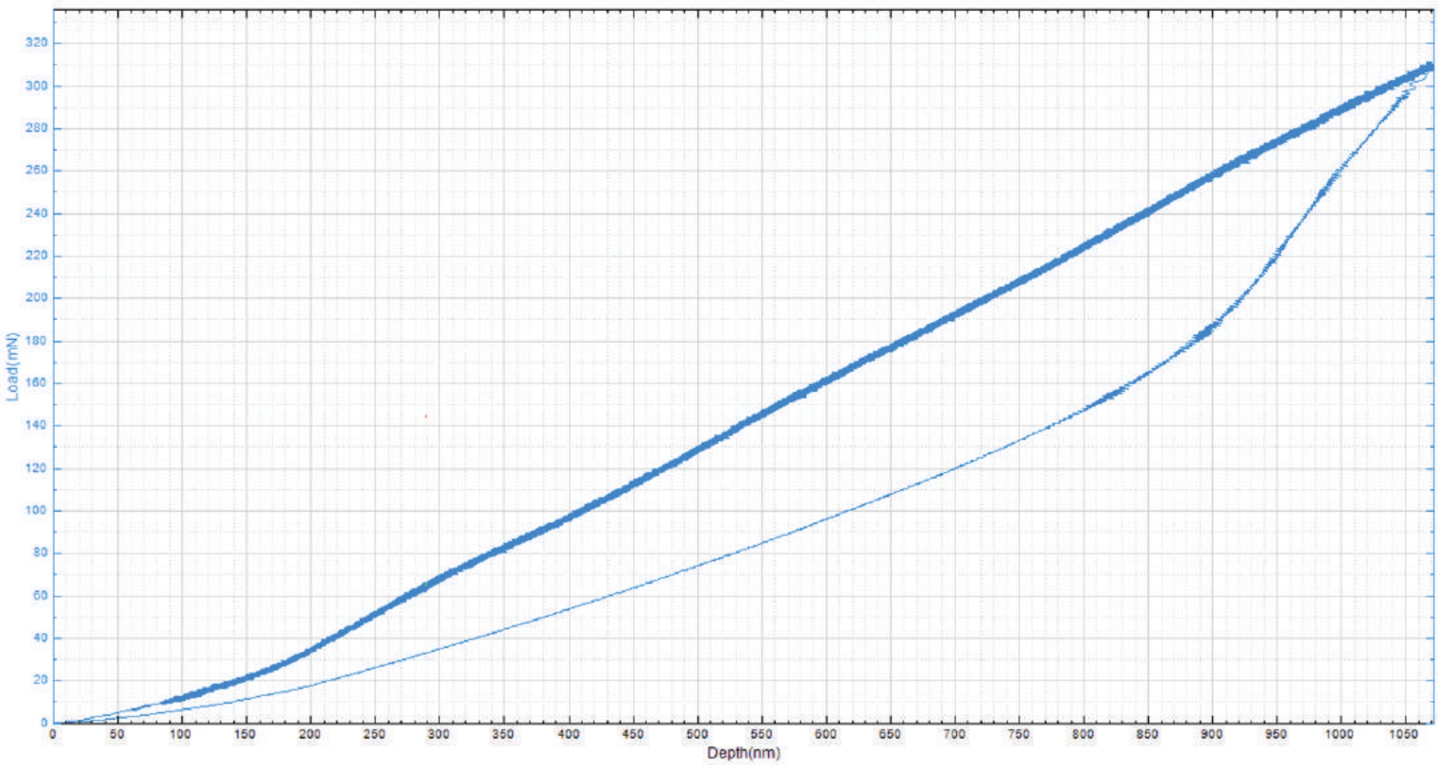


Figure 2: Load versus depth for the CSM test on steel.

We determined stress and strain from the information obtained at each cycle. The maximum load and depth at each cycle allows us to calculate the maximum stress applied in each cycle to the material. Strain is calculated from the residual depth at each cycle from the partial unloading. This allows us to calculate the radius of the residual imprint by dividing the radius of the tip to give the strain factor. Plotting stress versus strain for the material shows the elastic and plastic zones with the corresponding elastic limit stress. Our tests determined the transition between the elastic and plastic zones of the material to be around 0.076 strain with an elastic limit of 1.45 GPa.

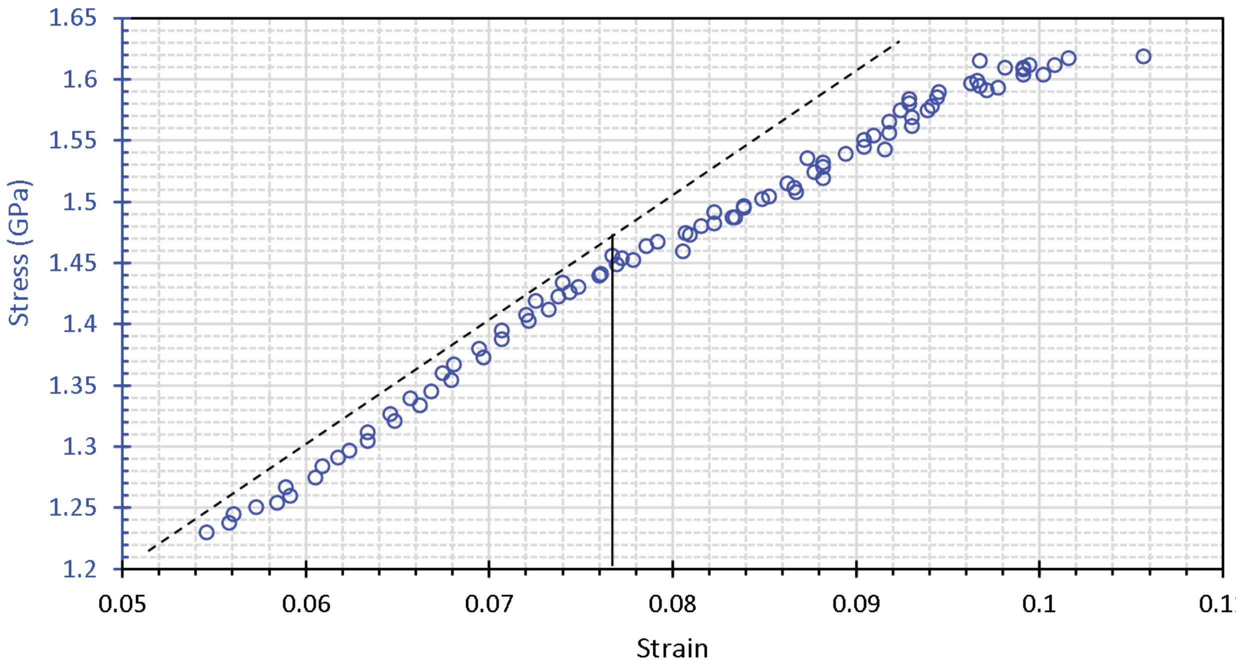


Figure 3: Stress (GPa) versus strain for the CSM test on steel.

Each cycle acts as a single indent so as we increase load, we run tests at various controlled depths in the steel. So, hardness and elastic modulus versus depth can be plotted directly from the data obtained for each cycle.

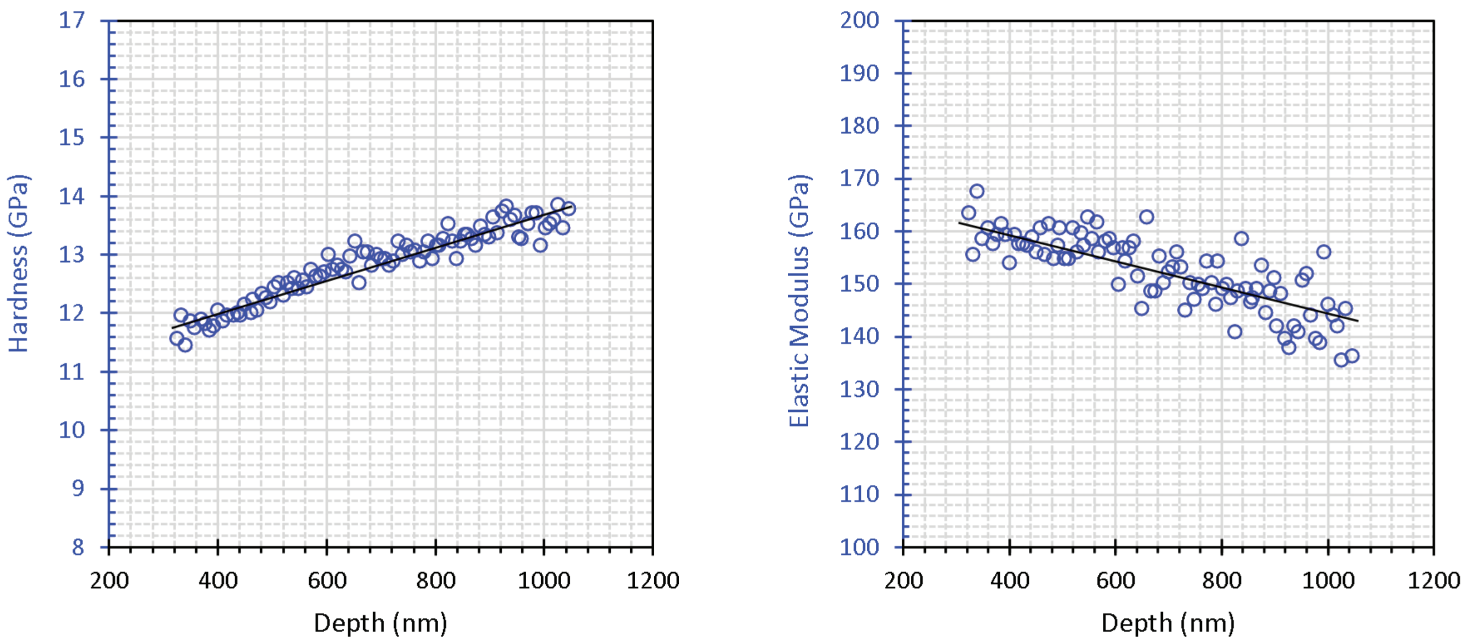


Figure 4: CSM measurements of hardness and elastic modulus as depth increases.

As the indenter travels into the material we see hardness increase and elastic modulus decrease.

www.nanovea.com
info@nanovea.com
euro@nanovea.com
mexinfo@nanovea.com

Conclusion

We have shown the Nanovea mechanical tester provides reliable stress-strain data. Using a spherical tip with CSM indentation allows for material property measurement under increased stress. Load and indenter radius can be changed to test various materials at controlled depths. Nanovea mechanical testers provide these indentation tests from the sub mN range to 400N.