3 POINT BEND TEST
USING MICROINDENTATION

Prepared by

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INTRO

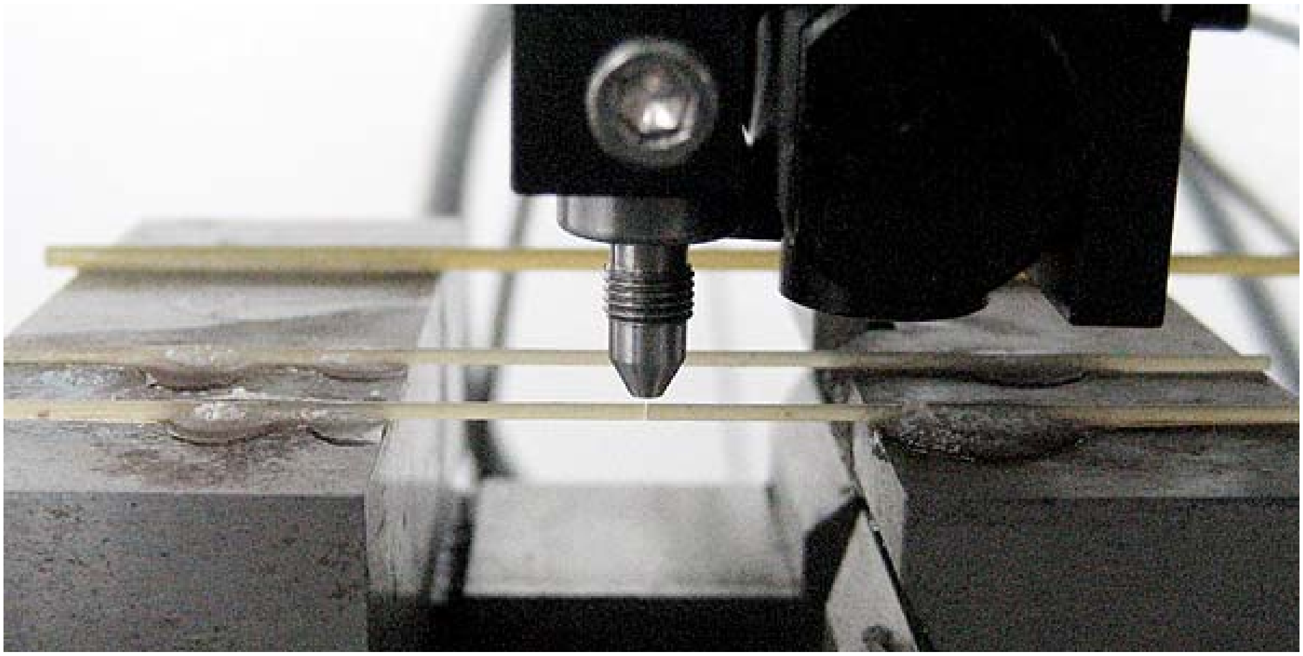
The 3 Point Bend Test is a common materials test and involves a wide range of loads. A broad range of samples tested (metals, composites, rock, concrete and plastics) are flat or rectangular rods with various geometries. Samples are supported on each end while a load is applied to its middle (3 Point Bend). The data retrieved from the test can provide vital information about flexural strength, performance, durability and service life.

IMPORTANCE OF MICROINDENTATION 3 POINT BEND TEST

Standard 3 Point Bend Tests are not capable of the low and sensitive loads provided by Microindentation and fail to provide adequate precision depth data for delicate samples. The Nanovea Nano or Microindentation mode provides the ability to precisely measure the tensile elastic modulus and critical load of a wide range of sensitive materials.

MEASUREMENT OBJECTIVE

In this application, the Nanovea Mechanical Tester, in Microindentation mode (seen below), is used to measure the flexural strength (using 3 Point Bend) of various sized rod samples (pasta) to show a range of data. 2 different diameters were chosen to demonstrate both elastic and brittle characteristics. Using a flat tip indenter to apply a point load, we determine stiffness (Young's Modulus) and identify the critical loads at which the sample will fracture.

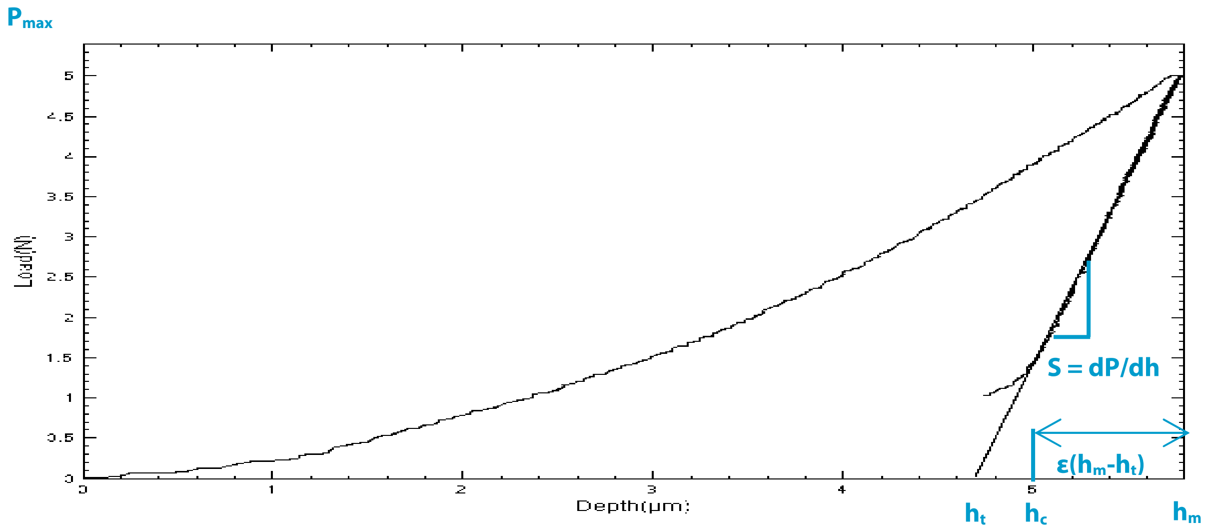


MICROINDENTATION MEASURMENT (MHT)

Microindentation is based on the standards for instrumented indentation, ASTM E2546 and ISO 14577. It uses an established method where an indenter tip with a known geometry is driven into a specific site of the material to be tested, by applying an increasing normal load. When reaching a pre-set maximum value, the normal load is reduced until partial or complete relaxation occurs. This procedure is performed repetitively; at each stage of the experiment the position of the indenter relative to the sample surface is precisely monitored with an optical non-contact depth sensor. For each loading/unloading cycle, the applied load value is plotted with respect to the corresponding position of the indenter. The resulting load/displacement curves provide data specific to the mechanical nature of the material under examination. Established models are used to calculate quantitative hardness and modulus values for such data. The MHT is especially suited to perform tests of penetration depths in the micrometer scale and has the following specifications: • Displacement measurement: Non-contact optical sensor • Displacement resolution: 10 nm • Maximum Indenter range: 300μm • Load application: Z motor controlled with force feedback loop • Load range: 0–30N • Normal load noise floor resolution: 1.5mN • Minimum load: 10mN • Maximum load: 30N • Contact force hold time: Unlimited.

Analysis of Indentation Curve

A typical load/displacement curve is shown below, from which the compliance C = 1/S (which is the inverse of the contact stiffness) and the contact depth hc are determined after correction for thermal drift.



Calculation of Young's Modulus and Hardness

Young's Modulus: The reduced modulus, E_r, is given by: $E_r = \frac{\sqrt{\pi}}{2}\frac{S}{\sqrt{A_c}} = \frac{\sqrt{\pi}}{2}\frac{1}{C}\frac{1}{\sqrt{A_c}}$ which can be calculated having derived S and A_c from the indentation curve using the area function, A_c being the projected contact area. The Young's modulus, E, can then be obtained from: $\frac{1}{E_r} = \frac{1-\nu^2}{E} + \frac{1-\nu_i^2}{E_i}$ where E_i and ν_i are the Young's modulus and Poisson coefficient of the indenter and E and ν the Young Modulus and Poisson coefficient of the tested sample. Hardness: The hardness is determined from the maximum load, P_{max}, divided by the projected contact area, A_c: $H = \frac{P_{max}}{A_c}$

TEST CONDITIONS

The following indentation parameters were used:

Applied Force (N)	7
Loading Rate (N/min)	1
Unloading Rate (N/min)	1
Indenter Type	Flat 1 mm

CALCULATING YOUNG'S MODULUS

Deflection is the displacement of a structural element under a load. For fixed-ended beams with point load in the center, deflection is related to Young's Modulus by the following equation:

$\delta = \frac{PL^3}{192 * E * I}$, where **P** is the applied point load, **L** is the length of the beam, **I** is the polar moment of inertia, and **E** is Young's Modulus.

The Polar Inertia for a rod is modeled by $\frac{\pi}{4} * R^4$. Given a measured load (P) at depth (δ) by the mechanical tester, Young's modulus is easily obtained.

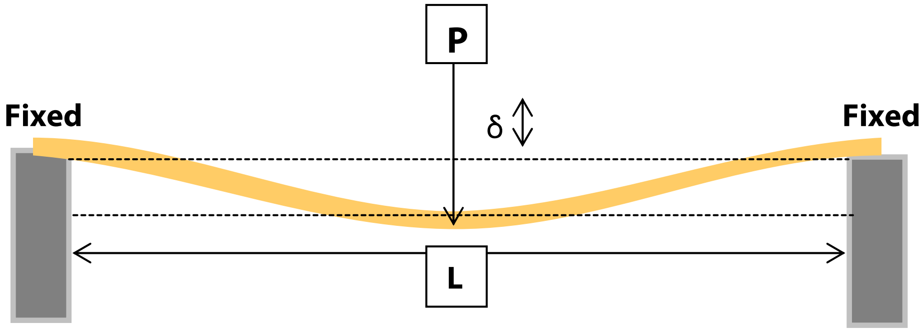


Figure 1: Diagram of 3 point load bending of fixed-end beam.

RESULTS

Specimen (Rod)	Sample 1	Sample 2	Sample 3
Diameter (mm)	0.90	0.95	1.67
L (mm)	25.00	25.00	25.00
Inertia	0.71	0.75	1.31
Load (N)	1.00	1.00	1.00
Depth (mm)	0.46	0.38	0.07
Young's Modulus (N/mm^2)	**252.43**	**288.38**	**893.67**

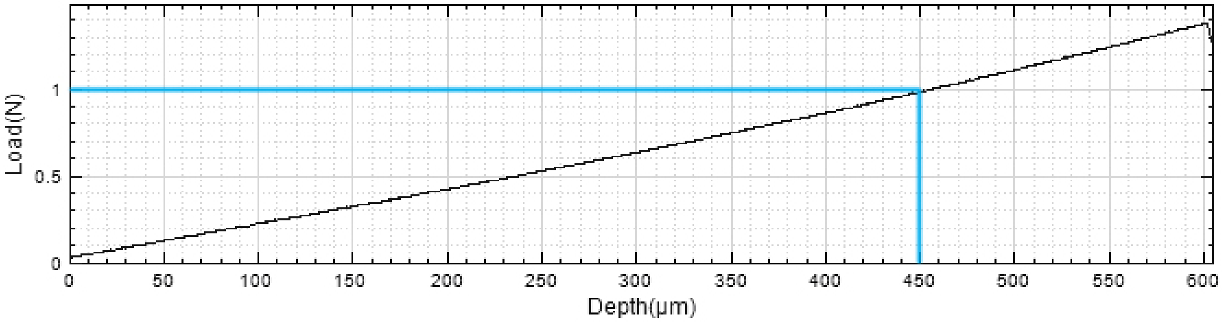
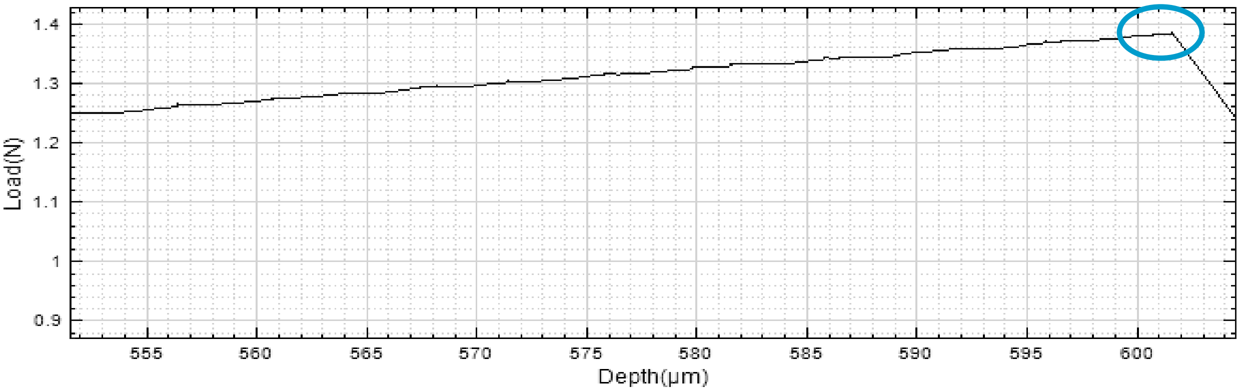


Figure 2: Load vs Depth of Sample 1

CRITICAL LOAD

The mechanical tester is able to identify what the critical depth and load at which the sample fractures.



Specimen (Rod)	Sample 1	Sample 2	Sample 3
Critical Depth (mm)	**0.601**	**0.486**	**0.431**
Critical Load (N)	**1.38**	**1.33**	**5.72**

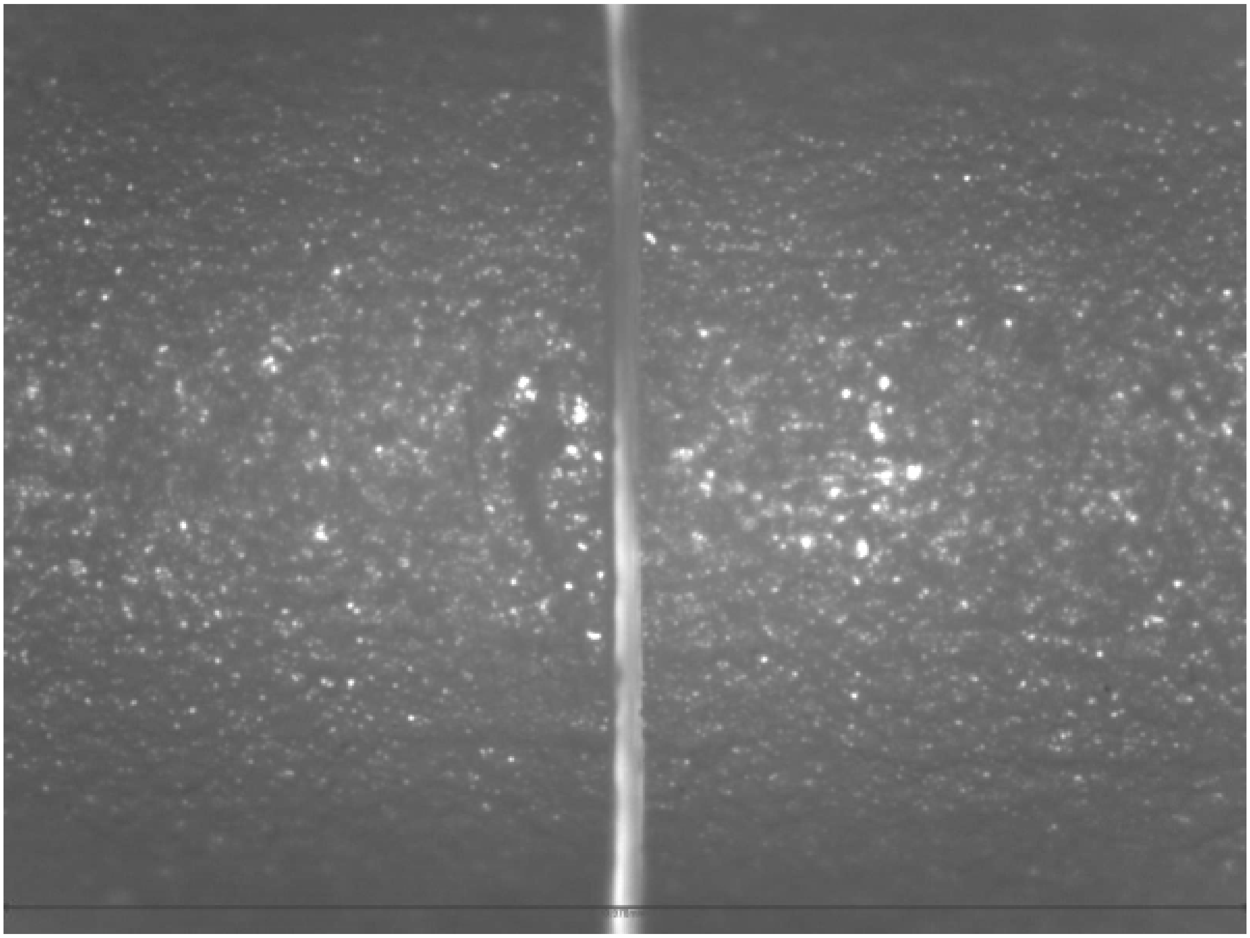


Figure 3: Sample 1 fracture (image width=.978 m)

CONCLUSION

In conclusion, we have shown how the Nanovea Mechanical Tester, in Microindentation mode, can determine tensile elastic modulus by using a 3 point bend test. Furthermore, it was illustrated that due to the precise load feedback loop, the system can be used to identify points, or critical loads and depths, at which brittle samples fail. The systems fast response provided quick removal of the load when testing the smaller sample before complete fracture failure. Displacement of up to 50mm in range and loads from the mN to 200N makes the Mechanical Tester an ideal tool for study using the 3 point bend method. The system can also extend in the nano range for applications where fracture loads are down to sub mN range. The system can also remove the load at a specific unloading rate and plot the return depth as to indicate the material overall elasticity to return to its original shape. Multiple loading at the same load could be used to study fatigue. This 3 point bending test opens an opportunity for studies of strengths and materials under different loading conditions and geometries. Unlike that of what is traditionally expected of a Nano or Micromechanical system.

Learn More about the Nanovea Mechanical Tester