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Dynamic Mechanical Analysis of Cork Using Nanoindentation

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INTRO

Cork is a material that is mostly used in the sealing and aging process for wines. Cork, a natural occurring material, is obtained from the bark of a specific oak tree: *Quercus suber L*.[1] The cork obtained from this tree has specific cell structures that gives it mechanical properties similar to synthetic polymers. In one axis, the cork has honeycomb structure. The two other axes are structured in multiple rectangular-like prisms. This gives cork different mechanical properties depending on the orientation being tested.

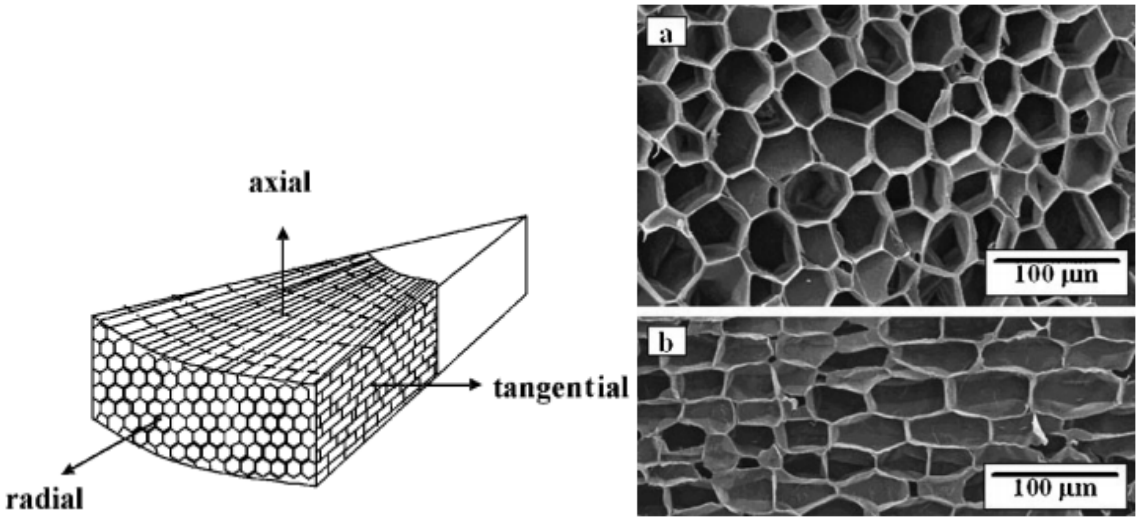
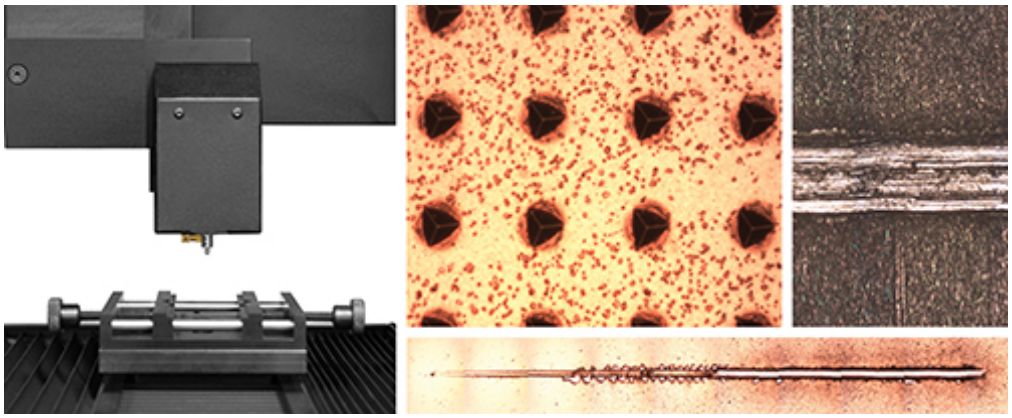


Figure 1: Schematic Representation of Cork (left) and SEM image (right) of a) radial section and b) tangential section. Obtained from Silva et al.[1]

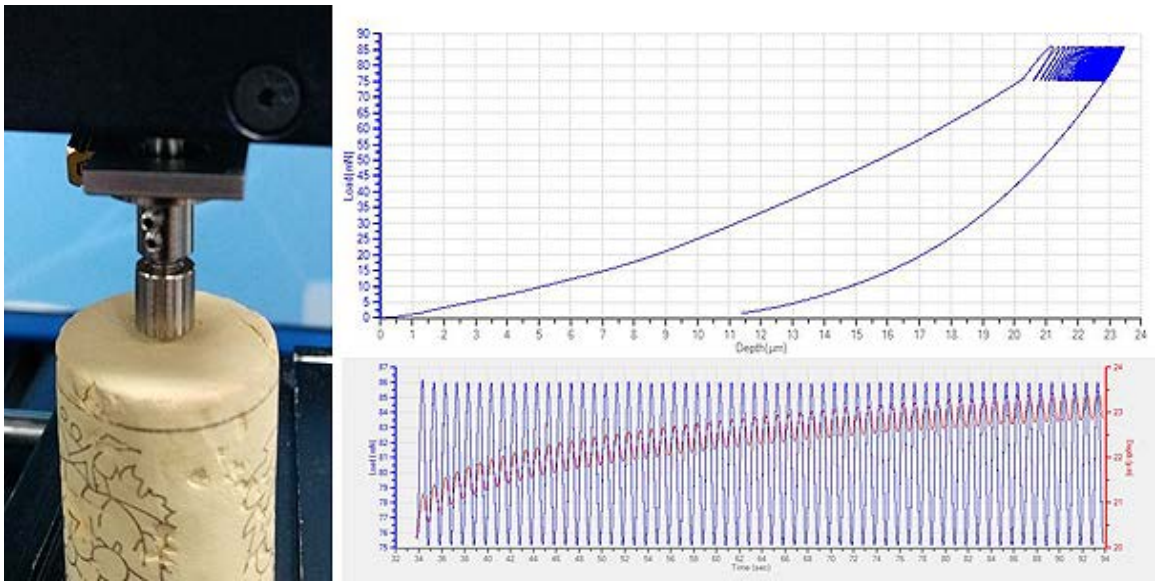
IMPORTANCE OF MECHANICAL TESTING IN CORKS WITH DMA

The quality of corks depends heavily on its mechanical and physical property. Its ability to seal wine can be identified as these important factors: flexibility, insulation, resilience, and impermeability to gas and liquids. By conducting dynamic mechanical analysis (DMA) testing, its flexibility and resilience properties can be gauged with a quantifiable method. These properties are characterized with Nanovea Mechanical Tester's Nano Module in the form of Young's modulus, storage modulus, loss modulus, and tan delta (tan (δ)). Other data that can be gathered from DMA testing are phase shift, hardness, stress, and strain of the material.



MEASUREMENT OBJECTIVE

In this study, four corks stoppers were tested with Nanovea's Mechanical Tester's Nano Module with dynamic mechanical analysis (DMA). The quality of the cork stoppers is labeled as followed: 1 – Flor, 2 – First, 3 – Colmated, 4 – Synthetic rubber. DMA indentation was conducted in both axial and radial directions on each cork stopper.



TEST CONDITIONS AND PROCEDURE

The following indentation parameters were used:

Test Parameters	All Samples
Maximum Force (mN)	75
Loading Rate (mN/min)	150
Unloading Rate (mN/min)	150
Amplitude	5mN
Frequency	1Hz
Creep (s)	60
Computation Method	ASTM E-2546 & Oliver & Pharr
Indenter Type	Ball, 3mm Diameter
Indenter Material	51200 Steel

RESULTS:

In the tables and graph below, the Young's modulus, storage modulus, loss modulus, and tan delta are compared between each sample and orientation. A quick description of each parameter is given:

Young's modulus: Stiffness; high values indicate stiff, low values indicate flexible

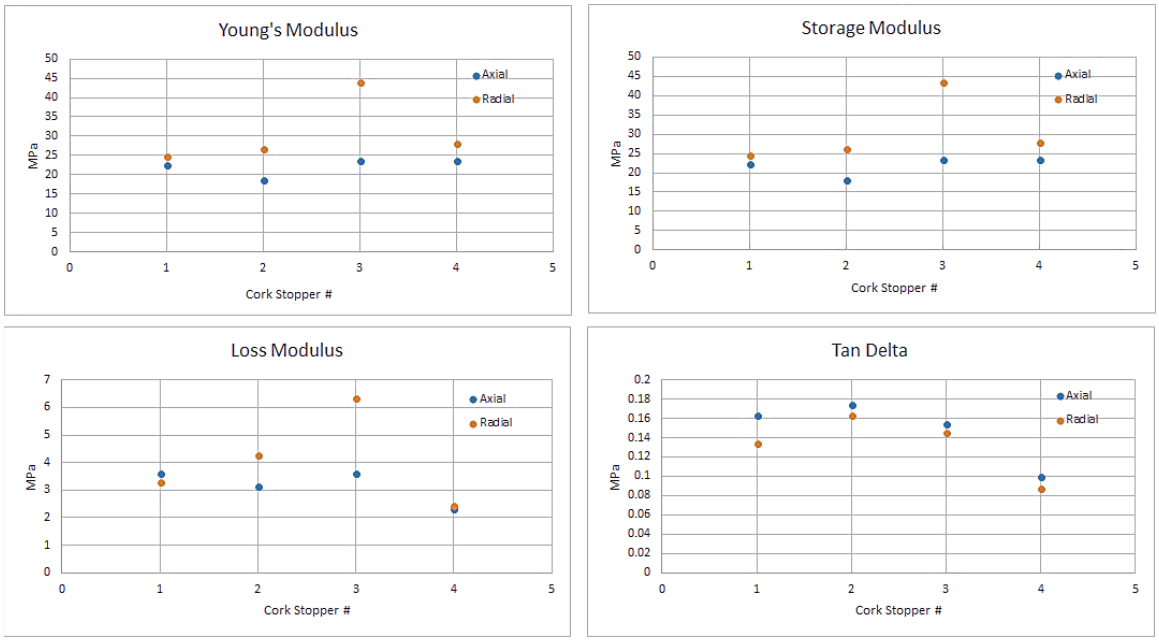
Storage modulus: Elastic response; energy stored in the material

Loss modulus: Viscous response; energy lost due to heat

Tan (δ): Dampening; high values indicate more dampening

Axial Orientation				
Stopper #	**Young's Modulus (MPa)**	**Storage Modulus (MPa)**	**Loss Modulus (MPa)**	**Tan (δ)**
1	22.5675	22.27209	3.624947	0.162964
2	18.54664	18.27153	3.162349	0.17409
3	23.75381	23.47267	3.617819	0.154592
4	23.6972	23.58064	2.347008	0.099539

Radial Orientation				
Stopper #	**Young's Modulus (MPa)**	**Storage Modulus (MPa)**	**Loss Modulus (MPa)**	**Tan (δ)**
1	24.78863	24.56542	3.308224	0.134865
2	26.66614	26.31739	4.286216	0.163006
3	44.07867	43.61426	6.365979	0.146033
4	28.04751	27.94148	2.435978	0.087173



Between cork stoppers, the young's modulus is not very different when tested in the axial orientation. Only Stopper #2 and #3 showed an apparent difference in the Young's modulus between the radial and axial direction. As a result, the storage modulus and loss modulus will also be higher in the radial direction than in the axial direction.

Stopper #4 shows similar characteristics with the natural cork stoppers, except in the loss modulus. This is quite interesting since it means the natural corks has a more viscous property than the synthetic rubber material.

CONCLUSION:

The Nanovea Mechanical Tester's Nano Module was able to successfully conduct DMA tests on four different cork stopper samples in two different orientation. Values for Young's modulus, storage modulus, loss modulus, and tan (δ) were obtained and compared between samples and orientation. Orientation shows prominent effects for some samples, but not all.

In addition to DMA tests, Nanovea Mechanical Tester's Nano Module can also conduct indentation tests and scratch tests. These tests allow the user to further explore the mechanical properties of their sample. Fracture toughness, yield strength, creep, delamination, scratch hardness, and other material properties can all be obtained with Nanovea's Mechanical Tester.

[1]Silva, S. P., et al. "Cork: properties, capabilities and applications." *International Materials Reviews*50.6 (2005): 345-365.

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