NANOVEA
A Better Measure

www.nanovea.com
info@nanovea.com
euroinfo@nanovea.com
mexinfo@nanovea.com
+1 (949) 461-9292

Viscoelastic Analysis of Rubber with Nanoindention DMA

Viscoelasticity is referred to as the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation.

A viscous material resists shear flow and strains linearly with time when a stress is applied, unlike an elastic material that strains immediately when stressed and returns to original state once the stress is removed. A viscoelastic material exhibits elements of both properties and therefore has a complex modulus.

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Importance of Nanoindentation DMA for Rubber

Tires are subjected to cyclical high deformations when vehicles are running on the road. When exposed to harsh road conditions, the service lifetime of the tires is jeopardized by many factors, such as the wear of the thread, the heat generated by friction, rubber aging, and others.

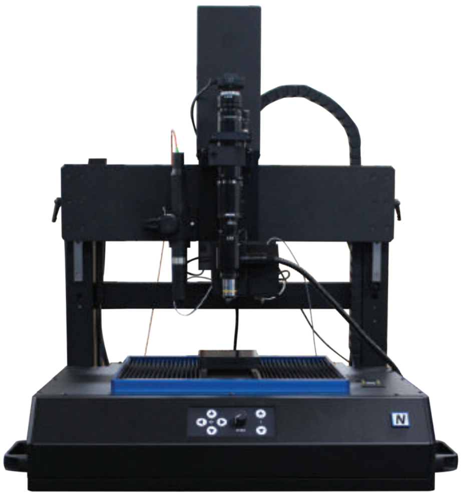
As a result, tires usually have composite layer structures made of carbon-filled rubber, nylon cords, and steel wires, etc. In particular, the composition of rubber at different areas of the tire systems is optimized to provide different functional properties, including but not limited to wear resistant thread, cushion rubber layer and hard rubber base layer.

A reliable and repeatable test of the viscoelastic behavior of rubber is critical in quality control and R&D of new tires, as well as evaluation of life span of old tires. Dynamic Mechanical Analysis (DMA) during Nanoindentation is a technique of characterizing the viscoelasticity. When controlled oscillatory stress is applied, the resulting strain is measured, allowing users to determine the complex modulus of the tested materials.

Objectives and Equipment

Equipment Featured

NANOVEA PB1000



Standard

Fully Upgradeable

Nano to Macro Range with no need to exchange

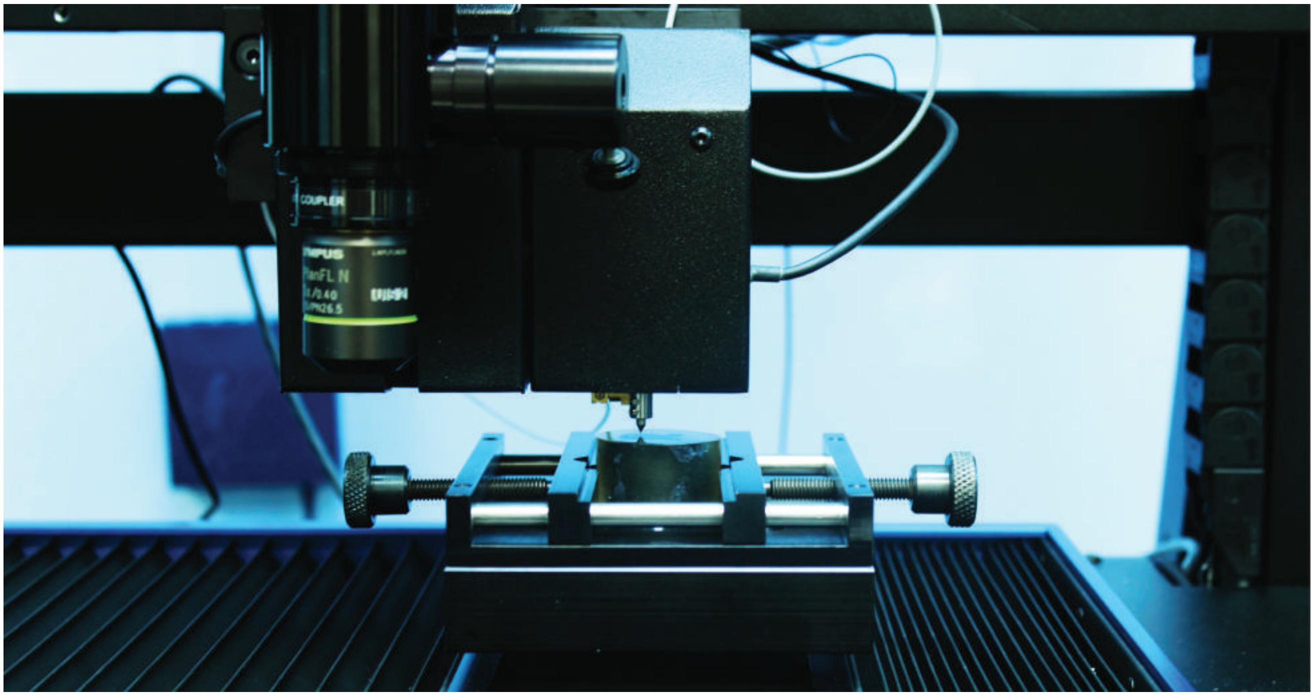
Robust and Low Cost of Ownership

Spacious Platform with Adjustable Height Clearance

https://nanovea.com/instruments/?p=mechanicaltesters

Measurement Objectives

In this application, the Nanovea Mechanical Tester, in Nanoindentation mode with DMA is used to study the comparative viscoelastic properties of rubber at different thicknesses of a tire sample.



Tire sample on Nanovea Mechanical Tester

Testing Conditions

A series (40 points) of nanoindentation DMA was performed along the thickness of the tire sample and the distribution of the indentations is illustrated in Fig. 3. The test conditions are summarized in Table 1.

Table 1: Test conditions of the nanoindentation

Test Parameter	Value
Maximum Force (mN)	**75**
Loading Rate (mN/min)	**150**
Creep (s)	**20**
Amplitude	**15**
Frequency (Hz)	**10**
Indenter Type	**100 µm spherical diamond**

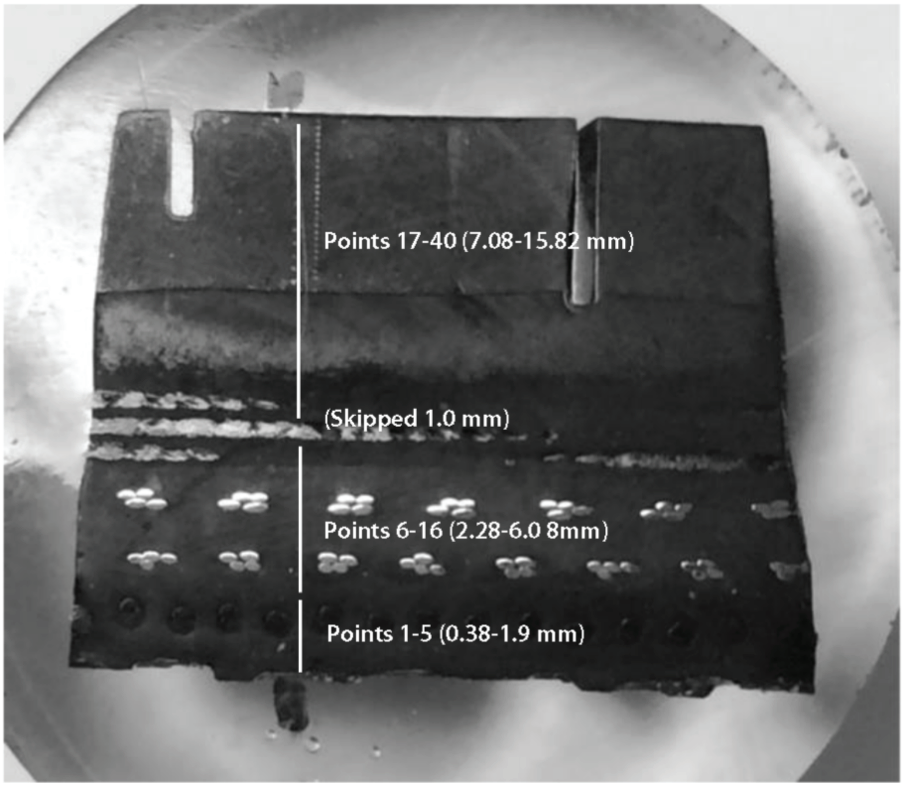


Figure 1 : Distribution of the indentation on the cross section of the tire sample.

Results and Discussion

40 indentations along the tire thickness were performed spaced 0.38 mm apart for a total distance of ~15.5 mm as illustrated in Fig. 3 and the corresponding Tan (δ), Storage Modulus, Loss Modulus and Hardness measured from the DMA are summarized in Fig. 4 to Fig. 7.

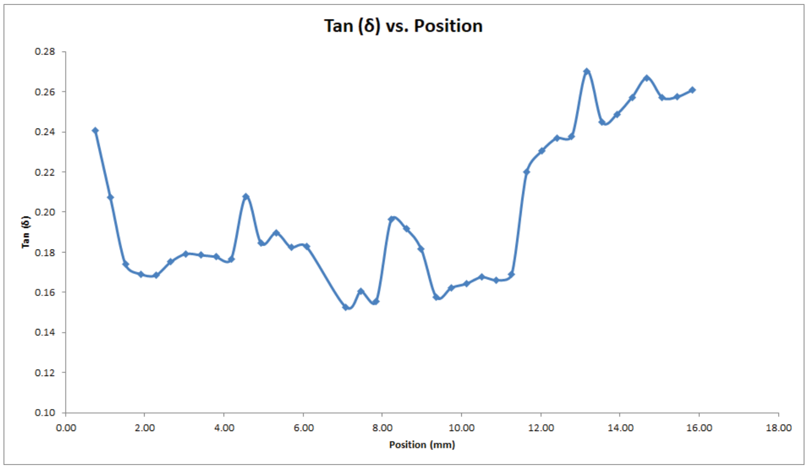


Figure 2 : Distribution of Tan (δ) at different locations of the tire.

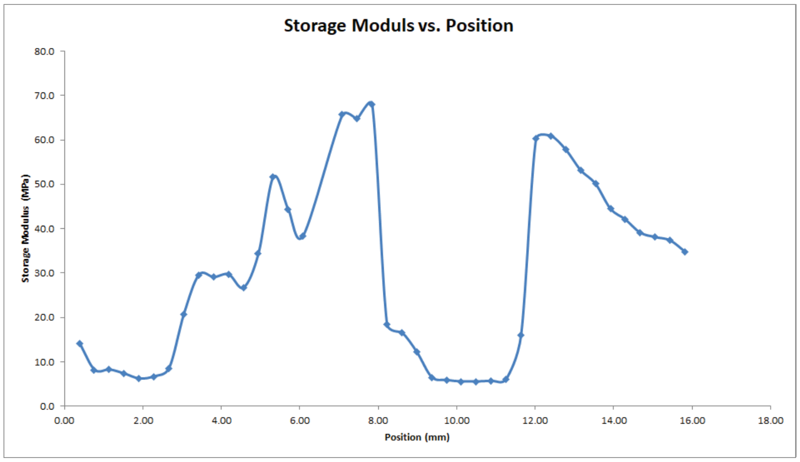


Figure 3 : Distribution of Storage Modulus at different locations of the tire.

Results and Discussion

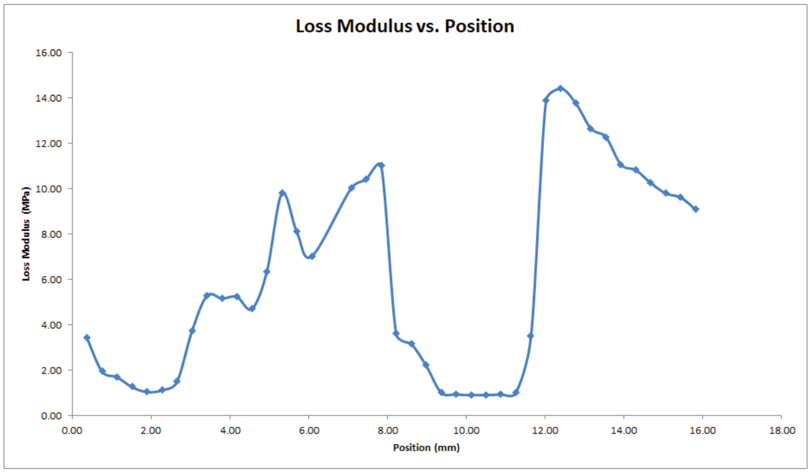


Figure 4 : Distribution of Loss Modulus at different locations of the tire.

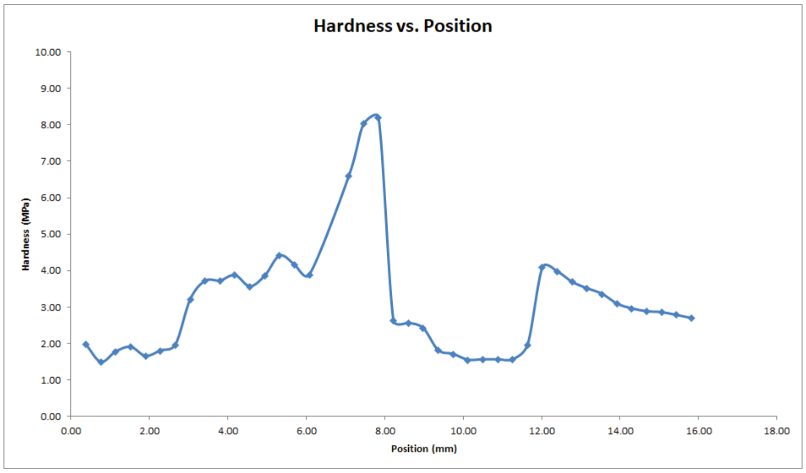


Figure 5 : Distribution of Hardness at different locations of the tire.

The distribution of the hardness and complex modulus meets the functionality requirements of the rubber at different layers of the tires. The rubber at the positions from 0.38 to 2.66 mm and from 8.22 and 11.64 mm exhibits a relatively low hardness below 2 MPa and low complex modulus. Such a relative soft feature allows the rubber in these regions to serve as a cushion layer and absorb the shocks and vibrations. In comparison, the rubber at the positions from 3.04 to 7.84 mm shows an enhanced hardness and complex modulus, due to the composite structure consisting of reinforcing fabric or high tensile-strength steel wires encased in the rubber compound. The enhanced mechanical properties of this layer provide the tire structure strength and toughness. The positions from 12.02 to 15.82 mm reside in the tire tread and exhibit higher Hardness and complex modulus compared with the "cushion region". The high carbon black concentration at this area gives reinforced abrasion resistance, cut resistance as well as traction.

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Conclusion

In this study, we demonstrate how the Nanovea Mechanical Tester in Nanoindentation DMA mode measures the viscoelastic properties of a rubber sample (used tire in this study). The profile seen across the depth of the tire shows how the different layers are used to create zones with very different behaviors. This is essential in tire design to decrease the vibration. Zones of high loss modulus will absorb differently than zones of low loss modulus. These types of studies are now essential to improve tires for smoother, safer rides that last as long as possible in different weather conditions. These tests can be performed at various temperatures and even under liquids. The test can also be conducted at various frequencies to mimic the behavior of tires as speed increases. Frequencies of 10Hz, used in this report, correspond to speed of about 67Km per hour. The Nanovea DMA can go up to 100Hz and is also possible to scan across various frequencies to obtain a sweep.

The Nanovea Mechanical Tester has true close feedback control on load applied. The load application with the fast piezo is independent from the load measurement done by a separate high sensitivity strain gage. This gives a distinct advantage during DMA since the phase between depth and load is measured directly from the data collected from the sensor. The calculation of phase is direct and does not need mathematical modeling that adds inaccuracy to the resulting loss and storage modulus. This is not the case for coil systems.

In conclusion, DMA measures hardness, loss and storage modulus, complex modulus and Tan (δ) as a function of contact depth, time and frequency. The optional heating stage allows determination of materials phase transition temperature during DMA. The Nanovea Mechanical Testers provide unmatched multifunction Nano and Micro/Macro modules on a single platform. Both the Nano and Micro/Macro modules include scratch tester, hardness tester and wear tester modes, providing the widest and most user friendly range of testing available on a single module.

To learn more about Nanovea Mechanical Tester or Lab Services.

www.nanovea.com
info@nanovea.com
euroinfo@nanovea.com
mexinfo@nanovea.com
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Thank you for reading!

We appreciate your interest in our technology and services. Read more about all of our product line and lab services at www.nanovea.com

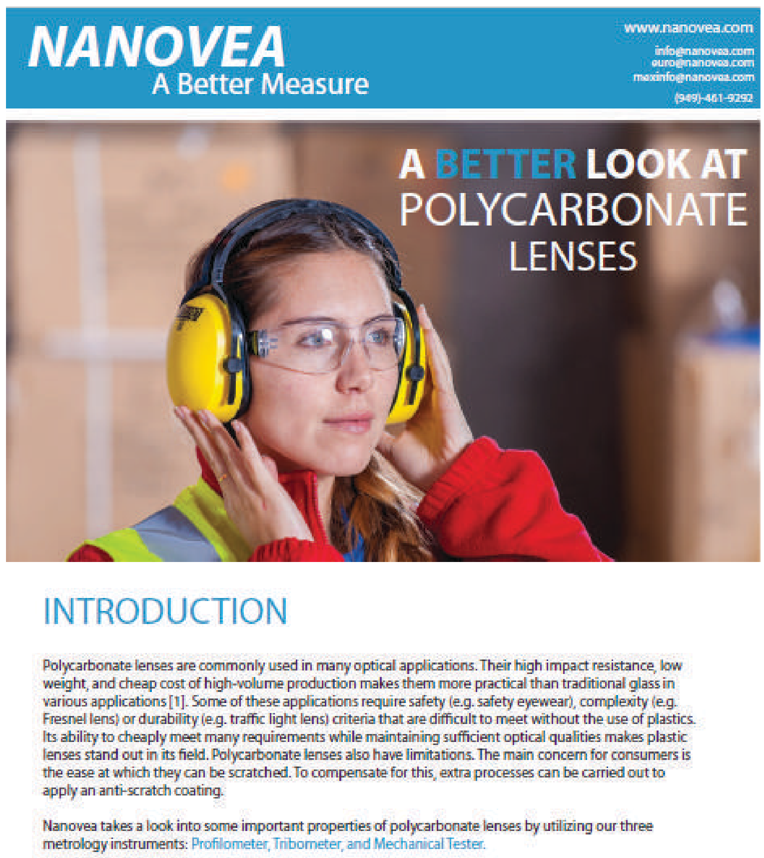
Call to Schedule a demo today!

If you have any questions please email us at info@nanovea.com

Recommended Reading

Check out our other application note where we conduct an extensive investigation on the materials property of Polycarbonate Lenses!

https://nanovea.com/investigating-the-properties-of-plastic-lens/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A BETTER LOOK AT POLYCARBONATE LENSES

INTRODUCTION

Polycarbonate lenses are commonly used in many optical applications. Their high impact resistance, low weight, and cheap cost of high-volume production makes them more practical than traditional glass in various applications [1]. Some of these applications require safety (e.g. safety eyewear), complexity (e.g. Fresnel lens) or durability (e.g. traffic light lens) criteria that are difficult to meet without the use of plastics. Its ability to cheaply meet many requirements while maintaining sufficient optical qualities makes plastic lenses stand out in its field. Polycarbonate lenses also have limitations. The main concern for consumers is the ease at which they can be scratched. To compensate for this, extra processes can be carried out to apply an anti-scratch coating.

Nanovea takes a look into some important properties of polycarbonate lenses by utilizing our three metrology instruments: Profilometer, Tribometer, and Mechanical Tester.