Fast Mechanical Characterization of an Epoxy Composite

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Introduction

Composite materials are the materials-of-choice for the electronics and aerospace industries because of their high strength, high modulus, high stiffness, low weight, chemical resistance, good weatherability, and manufacturing ease. As performance improves, other properties are affected, and the processing window often gets smaller.

Storage Modulus has been widely accepted as a tool to characterize impact properties, processability, dimensional stability (warpage), and effects of aging. The Storage Modulus has also been used to characterize the degree of cure, effects of modifiers, tougheners, extenders, fire retardants and other additives. Examination of a material's modulus at room temperature is a deceptively simple, yet effective, test that can yield useful information about a composite.

Purpose

Perform a fast and accurate dynamic modulus analysis of an epoxy composite at room temperature.

Experiment

The sample, an epoxy composite, was analyzed using the Perkin-Elmer DMA 7 Dynamic Mechanical Analyzer and 7 Series/UNIX® software. The analyzer was equipped with the stainless steel three-point bending measuring system with a 15-mm platform. Using tweezers, the sample was placed on the platform and the furnace was raised around the sample. No further sample preparation or clamping was required.

Three tests were performed to assure repeatability using the same parameters. Each test was performed and plotted in about 3 minutes.

TABLE 1: DMA7 Temperature/Time Scan Method

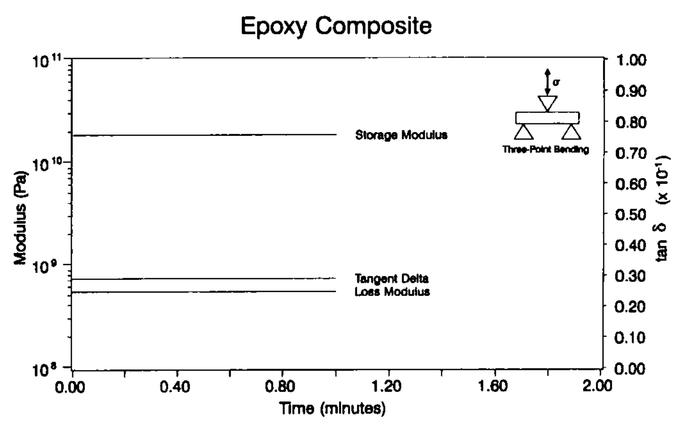
Sample	Epoxy Composite	
Instrument	Analyzer	Perkin-Elmer DMA7
	Measuring System	Three-Point Bending
	Geometry	Rectangle
	Sample Height (y)	0.865 mm
	Sample Width (x)	15.000 mm
	Sample Depth (z)	3.016 mm
Environment	Purge	Nitrogen (30 cc/min)
	Coolant	Ice Water
Parameters	Time	1 minute
	Temperature	Hold at 30°C
	Static Stress	1.10×10^7 Pa
	Dynamic Stress	1.00×10^7 Pa
	Frequency	10 Hz
Controls	Force	

Results

The Storage Modulus is plotted on a log scale of Modulus versus time. The Storage Modulus is 1.92 x 1010 Pa, which is in excellent agreement with the manufacturer's specification of 1.93 x 1010 Pa. The Storage Modulus is an indication of the ability of a material to store energy. The Storage Modulus can be increased by the effects of crystallization, degradation, annealing, internal stresses, further curing, advancement or post cure.

The Loss Modulus is plotted on the same scale as the Storage Modulus versus time. The Loss Modulus is 5.31 x 108 Pa, which is also in excellent agreement with the manufacturer's specification. The Loss Modulus is an indication of the ability of a material to dissipate energy, often in the form of heat or molecular rearrangements. The Loss Modulus can be increased by increased damping in the sample. Damping in a composite sample can be affected by free mobility, un-crosslinked epoxy, additives, plasticizers and tougheners.

The tangent delta curve is plotted on a linear scale versus time. The tan delta for this material is 0.0290 ±0.0005 at 30°C. This is in good agreement with literature values for the material in question. Tangent delta is independent of sample dimensions and can provide an even quicker indication of the properties of the composite. It is not necessary to measure the sample and enter sample dimensions if this is the only curve to be analyzed.



Conclusion

Composites can be quickly and accurately analyzed for Modulus. Modulus is sensitive to the degree of cure, staging, post cure and other effects. Applications include incoming, staged, cured and post cured materials. The Storage Modulus can be used to characterize impact properties, modulus, strength, creep, dimensional stability and other properties. This example, while specifically analyzing an epoxy composite, may prove useful on a wide variety of similar materials.

Further analysis may include characterization of the glass transition temperature or beta and gamma transitions. TMA7 analysis can be used to characterize the coefficient of thermal expansion. TGA7 analysis may also be included to characterize the weight percent of the various components or to analyze moisture absorption. DSC7 analysis may prove useful for further characterization of the high temperature transitions, cure and kinetics.