Features and Applications of the Dynamic Mechanical Analyzer NEXTA® DMA200

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1. Introduction

Dynamic mechanical analyzers (DMAs) are thermal-analysis instruments that measure dimensional variations in samples subjected to dynamic loading to determine various viscoelastic material properties—including storage modulus, loss modulus, and loss tangent—as functions of temperature.

The importance of understanding the viscoelastic properties of materials—an essential requirement in every industrial sector—has made DMAs widely-used tools for R&D and quality control for many types of materials, including polymeric materials and inorganic materials. To allow measurement of materials spanning a broad range of viscoelastic properties, DMAs use various distinct deformation modes, including bending deformations and tensile deformations, chosen appropriately based on the type of sample being measured.

Since the 1970s, we have been developing proprietary DMA systems and marketing them around the world. In 2023, we released the NEXTA® DMA200, a product representing a new generation of thermal-analyzer systems. In this report we describe the key features of the NEXTA® DMA200 and present sample measurements to illustrate its capabilities.

Fig. 1 NEXTA® DMA200 thermal analyzer.

2. Overview of the NEXTA® DMA200

In recent years, the growing trends toward hybridization and high functionality in materials and material constituents have created increasingly diverse, increasingly complex demands for thermal analyzers capable of characterizing the thermal properties of materials—and, specifically, how the functional properties and effects of various materials vary with changing temperature—from researchers in many fields of science and engineering, from basic research through product development. As one example, the growing use of lightweight, highly rigid *carbon-fiber reinforced plastics* (CFRPs) in mobility industries—particularly the aerospace and automotive sectors—has created a need for instruments capable of measuring highly elastic materials. On the other hand, in the field of electronic materials, increasingly stringent performance requirements and the progress of miniaturization have created a need for instruments capable of measuring thin, soft materials with low elastic modulus. In addition, considerations of safety and operational convenience have spurred growing demand for low-temperature cooling techniques that avoid the use of liquid nitrogen.

The NEXTA® DMA200, designed to meet these challenging market needs, boasts three key features:
(1) High load output for measurement of high elastic materials.
(2) High load resolution for measurement of low elastic materials.
(3) Gas chiller control unit allows measurements at temperatures as low as -100°C without liquid nitrogen.

3. Measuring High Elastic Materials

DMAs apply dynamic loads to samples and measure the resulting deformation. Consequently, measurements of high elastic materials require heavy loading to yield adequate sample deformation. In the NEXTA® DMA200, the force generator—the unit responsible for the load output from the instrument—has been redesigned to increase load output: whereas previous-generation instruments offered a maximum load output of 10 N, the NEXTA® DMA200 boasts a maximum load output of 20 N, a twofold increase. More specifically, this enhancement was achieved by upgrading the magnet in the force-generator unit—replacing the magnet used in previous-generation instruments with a more powerful magnet producing a stronger magnetic field—and by optimizing other aspects of the design, including the winding structure of the coil in the force-generator unit.

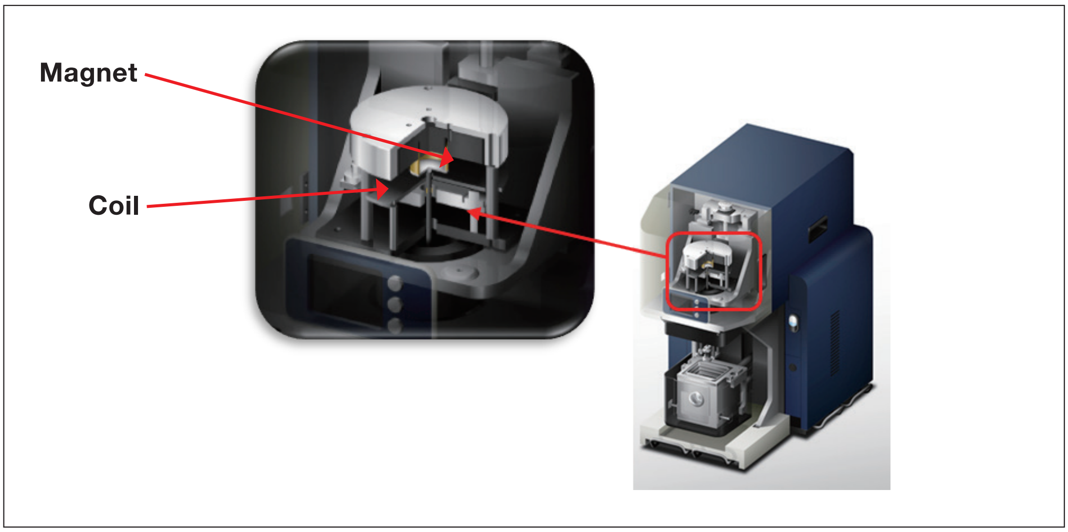

Fig. 2 Force-generator unit of DMA200.

To demonstrate the enhanced capabilities of the DMA200, we use it to measure the viscoelastic properties of CFRP, a high elastic material used for structural components in automobiles and aircraft. The material in question is made by impregnating carbon fibers with epoxy resin to enhance mechanical strength. Figure 3 shows the viscoelastic properties of CFRP as measured by the DMA200.

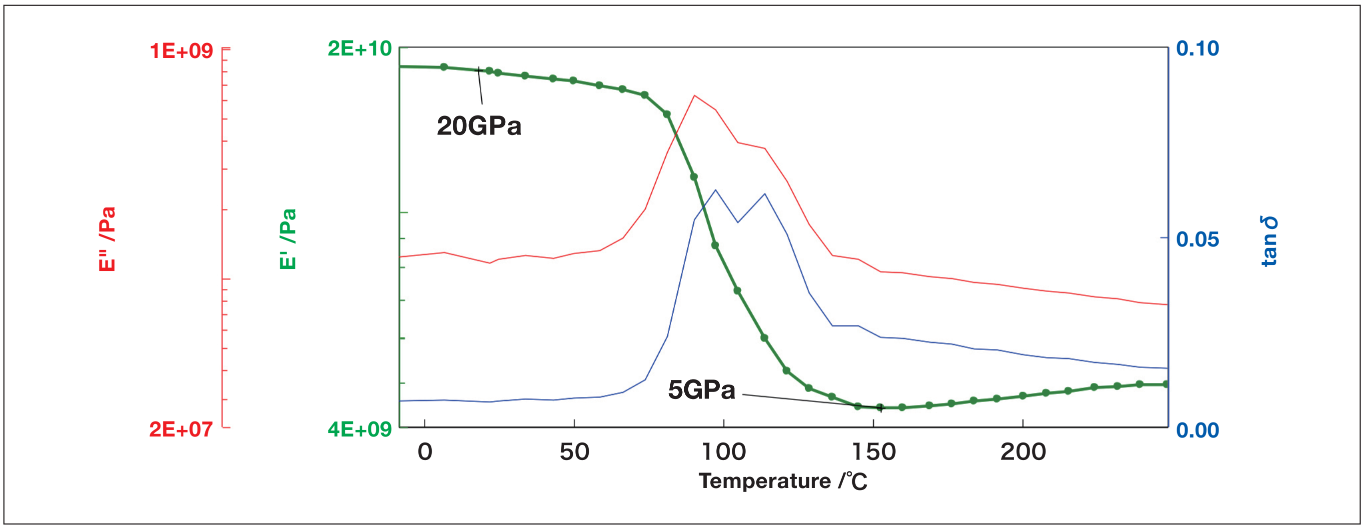

Fig. 3 Viscoelastic properties of carbon-fiber reinforced plastic (CFRP) material measured by DMA200.

The green, red, and blue curves in Figure 3 respectively indicate the storage modulus (E'), the loss modulus (E''), and the loss tangent (tan δ). From the green curve we see that the storage modulus for this material at 20°C is around 20 GPa, a high elastic modulus for a resin material.

As the temperature increases, the storage modulus decreases, plummeting rapidly beyond 80°C to a value of around 5 GPa at 150°C. From the other curves we see that the loss modulus and loss tangent peak between 50 and 150°C.

The rapid decrease in the storage modulus over this temperature range suggests that the material has a glass transition in the range 50–150°C. This example demonstrates that the DMA200, with its ability to output significantly higher loads than previous-generation instruments, easily handles measurements of high elastic materials such as CFRPs.

4. Measuring Low Elastic Materials

Measurements of low elastic materials require fine-grained control over load outputs (that is, high *load resolution*) to ensure that soft-material samples are appropriately deformed. The load output of a DMA is controlled by the current supplied to the force-generator unit; this current, in turn, is controlled by a D/A (digital-to-analog) converter. Because the resolution of this converter is fixed, increasing the maximum load output—and thus expanding the range of load outputs that the converter must encompass—has the effect of reducing the load resolution due to the finite dynamic range of the converter. The NEXTA® DMA200 circumvents this limitation by incorporating *two* D/A converters, one for high load outputs and one for low load outputs, thus allowing both high load output and high load resolution. (Patent pending.)

Figure 4 shows DMA200 measurements of a common anti-vibration gel, a low elastic material.

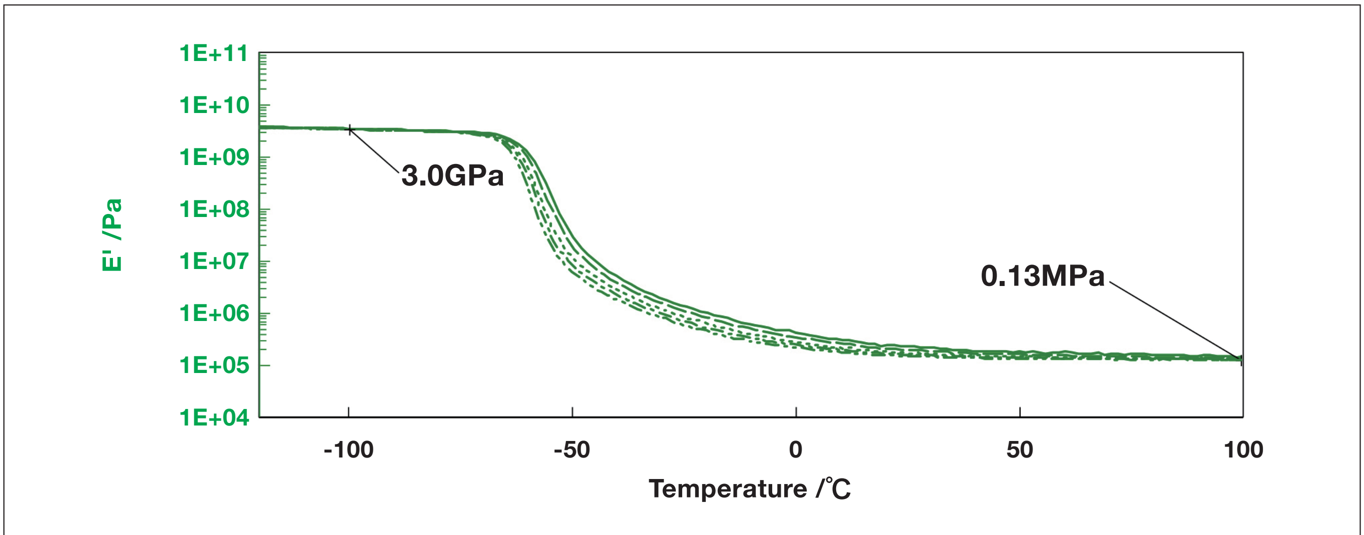

Fig. 4 DMA200 measurement of anti-vibration gel.

The green curve in Figure 4 shows the storage modulus (E'). At the low temperature of -100°C, the modulus exhibits a relatively high value of 3 GPa, indicating a glassy state.

The modulus begins to decrease rapidly above -50°C and converges to an approximately constant value around 0°C, indicating a rubbery state. At 100°C the storage modulus is only 0.13 MPa, demonstrating the ability of the DMA200 to make stable measurements of even minuscule elastic moduli.

5. Gas Chiller Control Unit Eliminates the Need for Liquid Nitrogen

DMA systems must be capable not only of heating samples, but also of cooling samples for low-temperature measurements. Previous-generation instruments were equipped with liquid-nitrogen cooling units that allowed samples to be cooled to temperatures below -100°C. However, the use of liquid nitrogen poses safety risks—including the dangers of handling ultra-cold liquid nitrogen itself, as well as the risk of suffocation due to nitrogen gasification—and increases operating costs.

For these reasons, the NEXTA® DMA200 incorporates not only the liquid-nitrogen cooling unit of previous-generation instruments but also a new cooling method based on electrical gas cooling, which allows samples to be cooled simply by connecting to a power supply. This gas-cooling system uses cooling circuits, driven by an internal compressor, to cool dried air to a temperature of -120°C; the DMA sample chamber is then cooled simply by injecting this cold air, eliminating any need to work with or refill supplies of liquid nitrogen.

Fig. 5 The DMA200 and its Gas Chiller Control Unit.

Figure 6 plots the sample temperature vs. time as the gas chiller control unit is used to cool the sample chamber from room temperature to low temperature. The sample temperature reaches -100°C after just 10.2 minutes of cooling, demonstrating the rapid-cooling capabilities of the gas-cooling approach. The new cooling system of the NEXTA® DMA200 not only improves safety and convenience by eliminating the need for liquid nitrogen, but also boasts powerful cooling performance to enable low-temperature measurements.

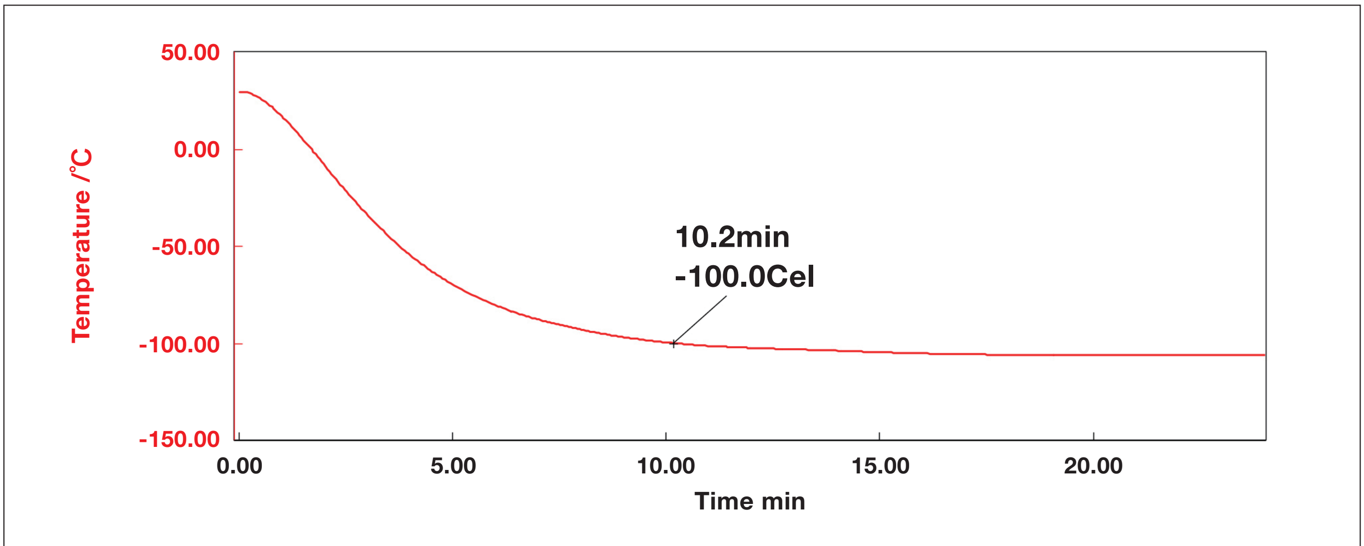

Fig. 6 Using the gas chiller control unit to cool the sample chamber.

6. Conclusions

The high load output and high load resolution of the NEXTA® DMA200 allow the system to measure materials spanning a broad range of elastic moduli, while the gas chiller control unit makes the instrument safer and more convenient to use than any of its predecessors. The NEXTA® DMA200 will meet the diverse viscoelastic-measurement needs of customers across a wide range of industrial sectors, from mobility to electronics and beyond.

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