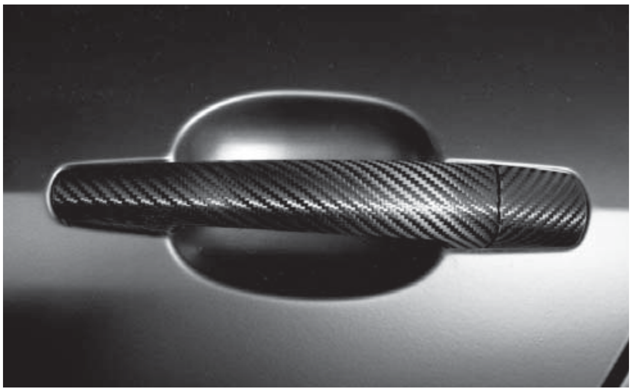
NETZSCH

Characterizing High-Modulus Composites



1 Use of carbon-fiber reinforced plastics in automotive industry

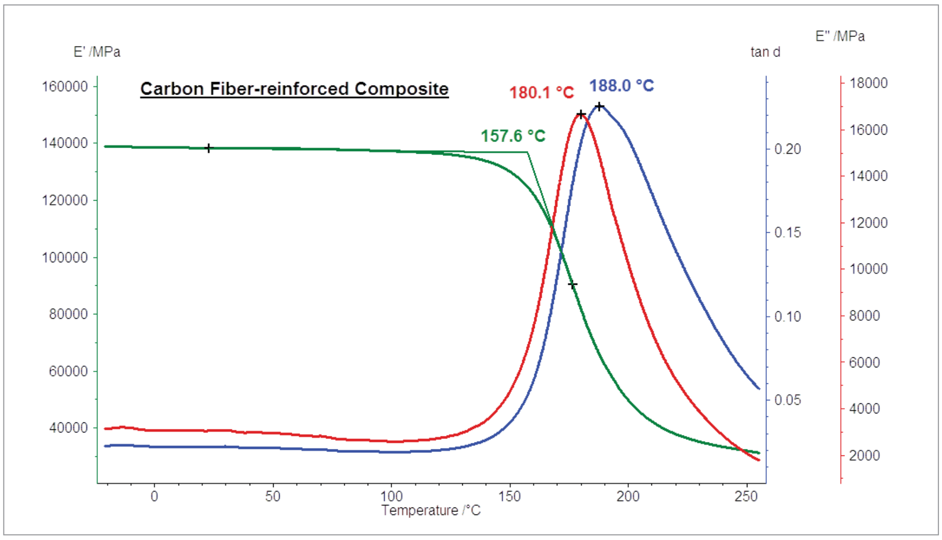
For many decades, steel was the primary material used in the automotive industry. In more recent years, a shift toward electric motors for safety and comfort has increased the popularity of lighter metals such as aluminum and magnesium, to counterbalance the resulting increases in vehicle weight. Today's research trends focus not only on purely electric vehicles, but also on hybrid cars, which have heavy batteries for their electric motor as well as a traditional engine with lower fuel consumption. Technological advancements such as these make it necessary to continuously seek lighter and lighter materials, but without sacrificing the required stiffness over a broad temperature range.

The key to reducing vehicular weight has been found in the use of fiber-reinforced polymers (fig. 1). These high-modulus composites have already proven their performance in the aircraft and aerospace industries. However, cycle times for the production of car parts are much faster and the thermosetting resin must therefore cure in only a few minutes, not a few hours.

Dynamic-Mechanical Analysis (DMA) – Method and Instrumentation

The focus of the DMA method is on the visco-elastic properties of polymers. The stiffness and damping behavior are determined under an oscillating force as a function of temperature, time and frequency. The robust, sturdy design of the versatile Dynamic-Mechanical Analyzer DMA E *Artemis* provides highly accurate Young's modulus values for all composites across the temperature range from -170°C to 600°C.

The measurement result in figure 2 shows the storage modulus E′ (green curve), loss modulus E′′ (red curve) and loss factor tanδ (blue curve) for a carbon-fiber reinforced epoxy resin as a function of temperature. The lamellar sample was measured in bending mode at a frequency of 10 Hz and a heating rate of 3 K/min. Prior to reaching 120°C, the material is even stiffer than titanium: 140000 MPa. At 158°C (extrapolated onset temperature of E′), the modulus drops due to the glass transition of the epoxy matrix. The corresponding peaks for E″ and tanδ are at 180°C and 188°C respectively.



2 DMA measurement result on a high-modulus carbon-fiber reinforced epoxy resin

NETZSCH-Gerätebau GmbH
Wittelsbacherstraße 42 · 95100 Selb · Germany
Phone: +49 9287/881-0 · Fax: +49 9287/881505
at@netzsch.com · www.netzsch.com

DMA 242 E *Artemis* – No Compromise for Composites

3 The versatile DMA 242 E *Artemis*

4 Sample holder for bending of composites

DMA 242 E *Artemis* – Advanced Features for Composites and More

The new DMA 242 E *Artemis* (fig. 3) offers many advantages in the research & development, quality control and failure analysis of composites. The modified single cantilever bending sample holder with free push-rod (fig. 4) guarantees quantitatively high storage modulus values (E’) at low damping values (E”, tanδ). Here, the sample is tightly fixed at one end and a free push-rod oscillates at the other end with a superimposed static force. For data acquisition, Fourier transformation carries out highly sensitive and accurate deformation amplitudes and the exact phase shift. This digital filtering improves the signal-to-noise ratio to one order of magnitude without any phase lag as compared to the conventional analog technique. The 5-dimensional system stiffness calibration routine for sample holder type, dynamic force, deformation amplitude, frequency and temperature takes into consideration all influencing factors from the DMA setup. Even the phase shift of the DMA electronics is taken into account by means of “rotation tuning”. This provides low tanδ values for extremely stiff materials such as composites, metals and ceramics.

DMA 242 E *Artemis* – At a Glance

- Robust and sturdy DMA design
- Special sample holder types
- Immersion test capability
- Fourier transformation of the data
- 5-dimensional system stiffness calibration
- Reliable quantitative data for high-modulus composites

NETZSCH-Gerätebau GmbH
Wittelsbacherstraße 42 · 95100 Selb · Germany
Phone: +49 9287/881-0 · Fax: +49 9287/881505
at@netzsch.com · www.netzsch.com

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