

Expansion Coefficient of Polymeric Materials using DMA 8000



Summary

The coefficient of thermal expansion (CTE) is an important property of materials. If the material is to be exposed to temperature gradients in its lifetime, it is often important to determine how much it will expand or contract over the temperature range. This application note details the method to determine the expansion coefficient of two polymers mounted in the PerkinElmer® DMA 8000 in tension mode. The methodology is relatively simple and this approach has been shown to give accurate expansion coefficients. These experiments are often referred to as being run in the “TMA mode” because the DMA 8000 is being used as a TMA in these cases.

Introduction

DMA normally works by applying an oscillating force to a material as shown in Figure 1 and the resultant displacement of the sample is measured. When determining expansion, the oscillating force function is turned off. The displacement of the sample is measured as it expands or contracts as a function of temperature. By plotting the displacement against temperature, the expansion coefficient can be calculated.

When a sample is placed in tension mode, the displacement gives an indication of how the geometry of the sample will change over the given temperature range. A calibration of the instrument with a known standard is required before the experiment, in order to compensate for the expansion of the driveshaft and clamps. This calibration can then be subtracted from the sample data to give an expansion curve relating to the sample alone. This method only works when in the glassy region for polymeric materials as, during the T_g, conformational changes have a dramatic impact on the geometry of the sample.

Results and conclusion

Measured displacement from the aluminum sample is graphed in Figure 2. This is expressed as total dL as it includes the expansion of the sample and the instrument. The expansion coefficient of aluminum is $2.5 \times 10^{-5} \text{K}^{-1}$ and the aluminum dL curve is the theoretical curve for the sample. By subtracting the aluminum curve from the total curve, the expansion associated with just the instrument can be plotted. The linear regression line is shown in yellow and the equation of this line is shown. This curve can now be subtracted from any unknown sample data to achieve the expansion from just the sample alone.

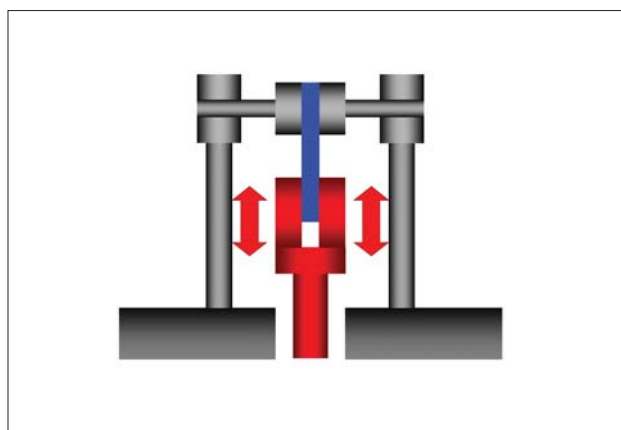


Figure 1. Sample fixture for tension mode.

Equipment	Experimental Conditions	
DMA 8000	Sample:	aluminum, PMMA, polycarbonate
	Geometry:	Tension, 10 mm length
	Temperature:	5 °C/min ⁻¹ Frequency: 1Hz

Experimental

1. Calibration of DMA for thermal expansion using aluminum.

The sample of aluminum was mounted in the tension clamps of the DMA. Data was collected from ambient to 180 °C. Tan δ and modulus were also collected by default but are not plotted for the purpose of this study.

2. Thermal expansion of PMMA and PC.

The sample was mounted in the same way as before and run to beyond the Tg of each material. Only data before the Tg is displayed for the purpose of this study.

Figure 3 shows data from PMMA. The displacement as a function of temperature is shown as the total dL. The sample dL is calculated by subtracting the instrument dL (from the previous experiment) from the total dL. This is the displacement resulting from the sample only. The tan δ response is shown indicating the Tg as a peak.

As discussed in the introduction, the expansion becomes non-linear as this is a conformational physical event in the sample. Above the Tg, the sample is distorting in this case and CTE values are not obtained. The expansion coefficient can be calculated from the sample dL data by dividing the slope of the linear portion of the data by the length of the sample. This gives an answer for PMMA of $1.96 \times 10^{-4} \text{K}^{-1}$.

The sample displacement against temperature for a polycarbonate can be seen in Figure 4. This time, only the glassy region is plotted and the instrument expansion has already been subtracted in the same way as the previous example. The equation of the linear regression line is given which gives an expansion coefficient of $1.7 \times 10^{-4} \text{K}^{-1}$ after the sample length has been accounted for.

This application note has demonstrated that a DMA can be used in “TMA mode” in order to determine expansion behavior of materials as a function of temperature. The expansion coefficient can be determined with ease without requiring another instrument.

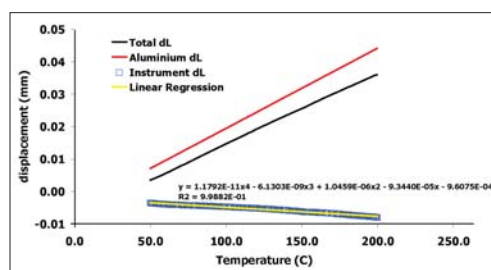


Figure 2. Displacement from aluminum sample.

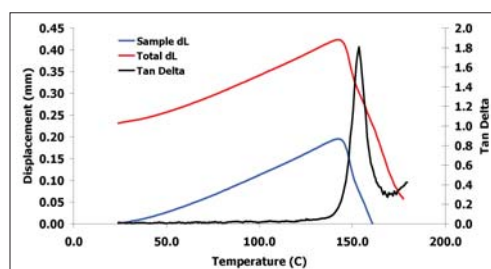


Figure 3. PMMA data.

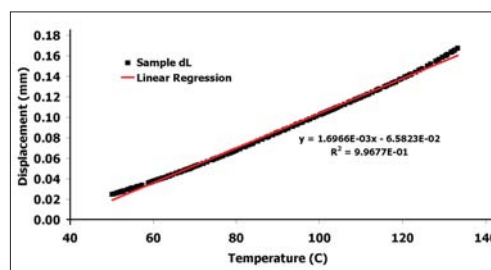


Figure 4. Sample displacement against temperature for a polycarbonate.