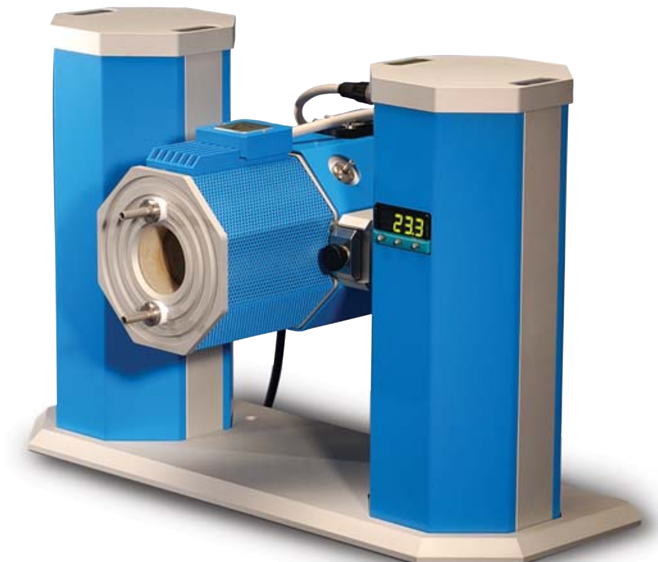
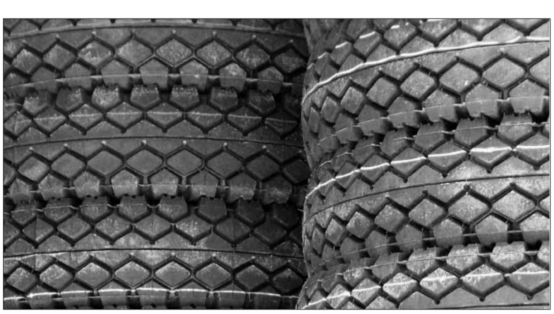
Characterization of Car Tire Rubber



Summary

The characterization of car tire rubber is demonstrated in this application note. Samples were taken from various places for a single car tire. The glass transition temperature is shown to vary depending on where the material was taken from the tire. Being a rubber, the modulus and also the damping properties change dramatically on passing from the glassy to the rubbery state. The different properties corresponding to different parts of the tire demonstrate the different materials that the tire is made from. It also shows where a mixture of materials is evident in one place.



Introduction

Dynamic Mechanical Analysis (DMA) is one of the most appropriate methods to investigate relaxation events. When the sample to be measured is rubbery at room temperature, this presents challenges to the experimenter in terms of clamping and the instrument in terms of the stiffness range of the sample going from a glassy to a rubbery state. Rubbery samples are normally examined in either shear or a bending geometry and this note examines single cantilever bending. How the experimental challenges can be overcome through the unique design of the PerkinElmer® DMA 8000 is discussed.

DMA works by applying an oscillating force to the material and the resultant displacement of the sample is measured. From this, the stiffness can be determined and the modulus and tan δ can be calculated. Tan δ is the ratio of the loss modulus to the storage modulus. By measuring the phase lag in the displacement compared to the applied force it is possible to determine the damping properties of the material. Tan δ is plotted against temperature and glass transition is normally observed as a peak since the material will absorb energy as it passes through the glass transition.

Most car tires are predominantly made from polybutadiene, but various grades of this material are used on different parts of the tire. DMA can be used to show where the various grades are located and areas where overlapping materials are evident.

Experimental

Temperature scan of car tire rubber.

A cross section of a single tire was obtained. It was further cut to produce samples from the tread, under the tread and from the sidewall near the tread. Due to the varying sample sizes, the dimensions of each sample varied. The sample was lightly mounted in the single cantilever bending clamps and cooled to approximately -100 °C (to ensure the sample was glassy). The clamps were tightened and the oven replaced to continue the cooling down to -150 °C.

Equipment		Experimental Conditions
DMA 8000	Sample:	Michelin® Car Tire
1L Dewar	Geometry:	Single Cantilever Bending
	Dimensions:	7.5–12.5 (l) x 4.9–9.0 (w) x 2.5–4.6 (t) mm
	Temperature:	-150 °C to 100 °C at 3 °C min^{-1}
	Frequency:	1.0 Hz

Results and conclusion

Figure 1 shows the glass transition of these materials as a peak in the tan δ and a drop in modulus. As stated in the experimental section, the sample was clamped only after it had reached a glassy state. This avoids spread in the clamps and makes the measurement more accurate. The DMA 8000 is designed so that the oven can be removed from the instrument very quickly to allow reclamping. This feature prevents significant condensation of water on the surface of the sample and also avoids the sample returning to a rubbery state before it was possible to tighten the clamps.

The data also shows a drop in modulus of three orders of magnitude. This is well within the instrument parameters and means that experiments where the stiffness of a material changes dramatically can be examined in a DMA 8000 in one experiment over the entire temperature range of interest.

It is clear that the various areas of the car tire are constructed from different materials. It is interesting that the sample taken from the sidewall near the tread shows two glass transitions indicating there is a mix of materials in this region. This is not surprising as this is the area where the tread and the sidewall meet. Car tires are manufactured from different materials because the different areas have to meet different requirements. The modulus and the glass transition are important considerations for these materials.

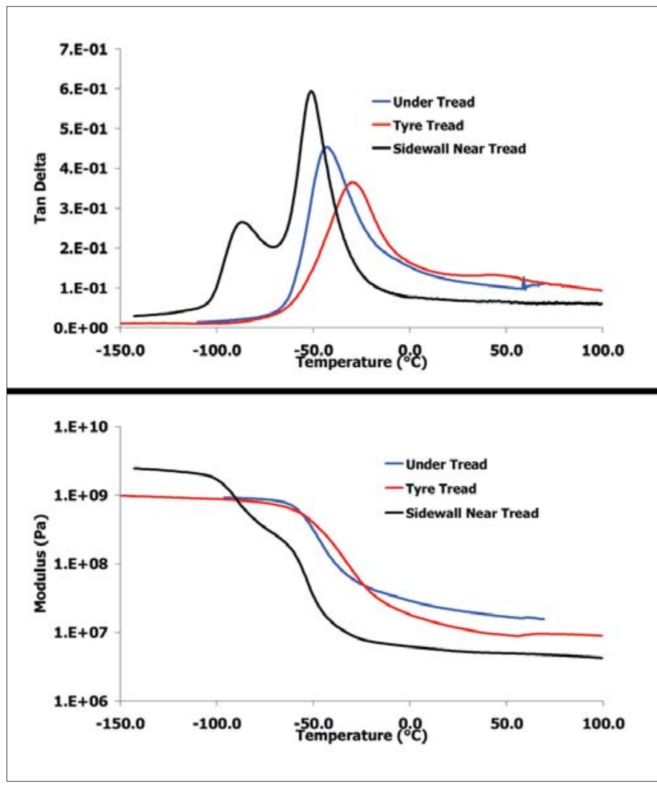


Figure 1. Glass transition of tire rubber.

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