Effect of Frequency on Viscoelastic Properties of Materials

KEYWORDS:

- > DMA
- > GLASS TRANSITION
- > TEMPERATURE RAMP
- > VISCOELASTIC PROPERTIES
- > FREQUENCY DEPENDENT

Introduction

To understand the viscoelastic behavior of a material, Dynamic Mechanical Analysis *(DMA)* is one of the most useful characterization techniques. It helps in understanding the response of a material's structure to different environmental conditions *(for example, frequency, temperature, load, etc.)*, resulting in optimization of mechanical properties.

Among these conditions, this application note focuses on the effect of frequency on the glass transition temperature (Tg) of an EPDM material.

All tests presented in this study were performed using the Alpha Metravib DMA+300.

Materials and Methods

The material tested was EPDM *(ethylene propylene diene monomer)*. EPDM is a durable synthetic rubber commonly used across many industries, such as tire manufacturing.

The specimens used were standard Goodrich cylindrical blocks with a diameter of 18mm and a height of 25mm. The specimens were studied in compression mode *(see Figure 2)*. A dynamic force of 10N was applied to the specimen, along with a static force of 20N to ensure that the specimen remained in contact with the specimen holders.

Figure 1.

Alpha Metravib DMA+300

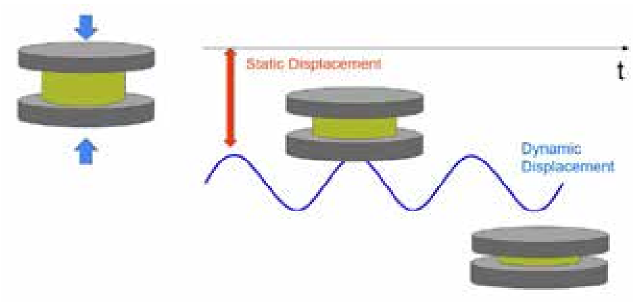

Figure 2.

Schematic diagram of compression mode

Since the objective was to demonstrate the effect of frequency on a material's glass transition temperature, a temperature ramp from −60°C to 100°C was performed at three different frequencies: 1Hz, 10Hz, and 50Hz. This test mode was selected because it is especially fast and provides more data points than a classic frequency sweep performed at multiple temperature stages. The test parameters are summarized in Table 1.

TABLE 1. TEST PARAMETERS	
DYNAMIC FORCE	10N
FREQUENCY	1Hz, 10Hz, 50Hz
STATIC FORCE	−20N
TEMPERATURE	−60°C to 100°C (60min stabilization at −60°C)
RATE	2°C/min
DMA	DMA+300
TEST MODE	Compression

Results

Figure 3 shows the results obtained from the temperature ramps performed at the three selected frequencies. The results are presented in terms of storage modulus (E′) and loss factor (tan δ) as a function of temperature. The decrease in E′ with increasing temperature indicates molecular dynamic rearrangements of elastomer chains between the glassy state *(localized molecular movement)* and the rubber-like state *(high-amplitude movement)* [1].

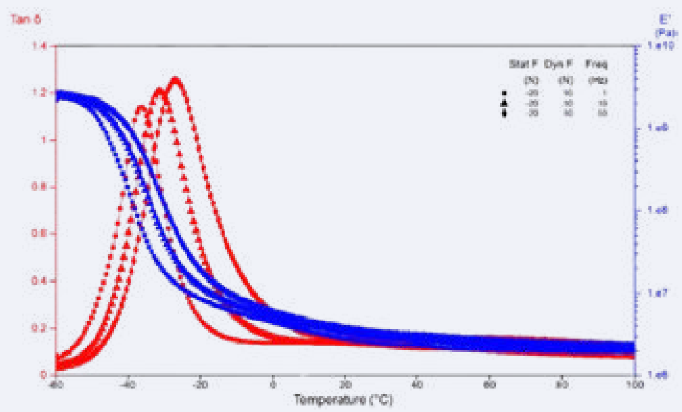

Figure 3.

E′ and tan δ as a function of temperature at 1Hz, 10Hz, and 50Hz

As shown in Figure 3, frequency has a clear effect on the glass transition temperature of the material. An increase in Tg with increasing frequency was observed, with Tg shifting from −36°C to −27°C as frequency increased from 1Hz to 50Hz.

An increase in tan δ magnitude with increasing frequency was also observed. At low frequencies, elastomer chains have more time to relax and respond, resulting in more viscous behavior and lower tan δ values. At higher frequencies, the chains have less time to relax and respond, leading to more elastic behavior and higher tan δ values.

Conclusions

This application note demonstrates the capability of the Metravib DMA+300 to characterize elastomer materials. Temperature ramps performed at different frequencies provided clear insight into the effect of frequency on the glass transition temperature of EPDM.

Additionally, the behavior of storage modulus (E′) and loss factor (tan δ) as a function of temperature was evaluated. Both glass transition temperature and tan δ magnitude were observed to increase with increasing frequency, which is correlated with differences in relaxation time available to the polymer chains.

KEY TAKEAWAY:

DMA temperature ramps show that increasing test frequency shifts the glass transition temperature and viscoelastic response of elastomer materials.

REFERENCES

1. Kevin P. Menard. Dynamic Mechanical Analysis: A Practical Introduction.

STANDARDS

ISO 6721, ASTM E1640

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