APPLICATION **SHEET**

Polymers · Polymer Manufacturing
DMA 242 E *Artemis*

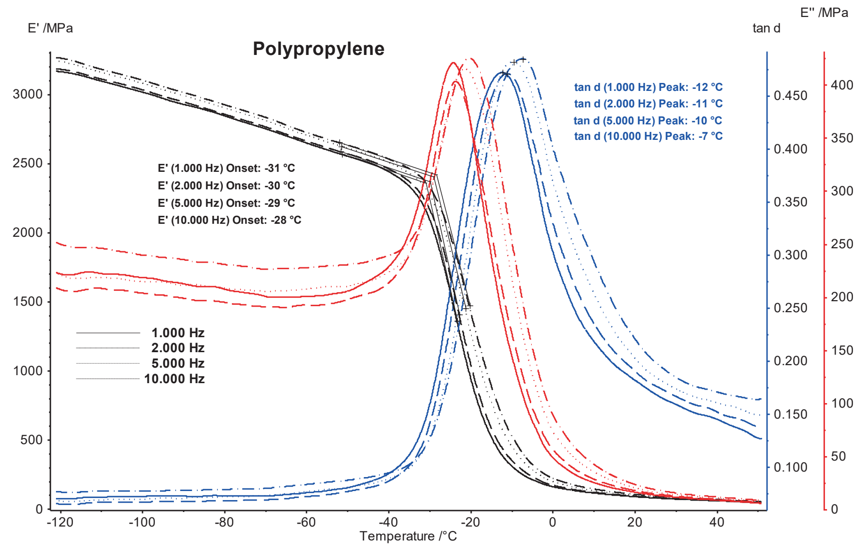
Polypropylene

Introduction

Polypropylene (PP, $(C_3H_6)n$) is a thermoplastic polymer of propylene. It has atactic, isotactic and syndiotactic forms dependent on the orientation of the methyl (CH_3) groups. As atactic PP, it lacks any crystalline structure, only the latter two are being used technically. PPs melting point of ~160°C makes it an easily workable thermoplastic, yet it can withstand dishwasher and industrial hot filling temperatures. Its good resistance to fatigue predetermines its use for living hinges. PP is therefore widely used in food and beverage packing, especially of dairy products.

Test Conditions

Temperature range:	-170°C ... 170°C
Heating/cooling rates:	2.5 K/min
Sample holder:	3-point bending, 20 mm
Amplitude:	± 40 µm
Frequency:	1, 2 and 5 Hz
Proportional factor:	1.2



Test Results

The multi-frequency run of a polypropylene sample is illustrated in the plot. The measurement was carried out at 1, 2, 5 and 10 Hz. The glass transition started at- 31°C for the storage modulus (black curve) at a frequency of 1 Hz. The corresponding peak in the E" curve (red) was at -24°C and at -12°C in the tan δ curve (blue). As expected, the temperature values for the glass transition and the curves themselves were shifted to higher values with increasing frequency. A master curve evaluation was done for the glass transition. By means of the time-temperature superposition principle (according to Williams-Landel-Ferry, WLF), the results of a multi-frequency DMA measurement can be transformed to temperature and frequency ranges which are of practical interest for the application of parts. According to WLF, the isothermal curves are shifted towards each other along a frequency axis such that a single curve results.

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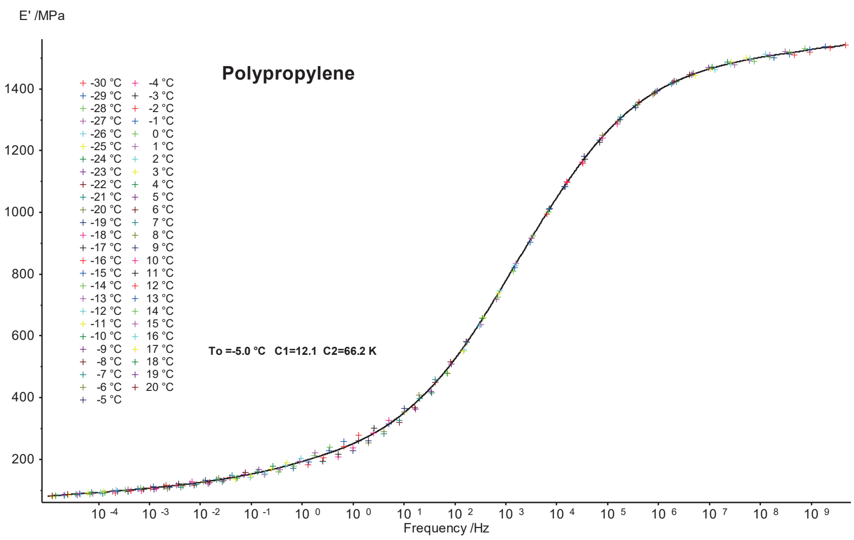

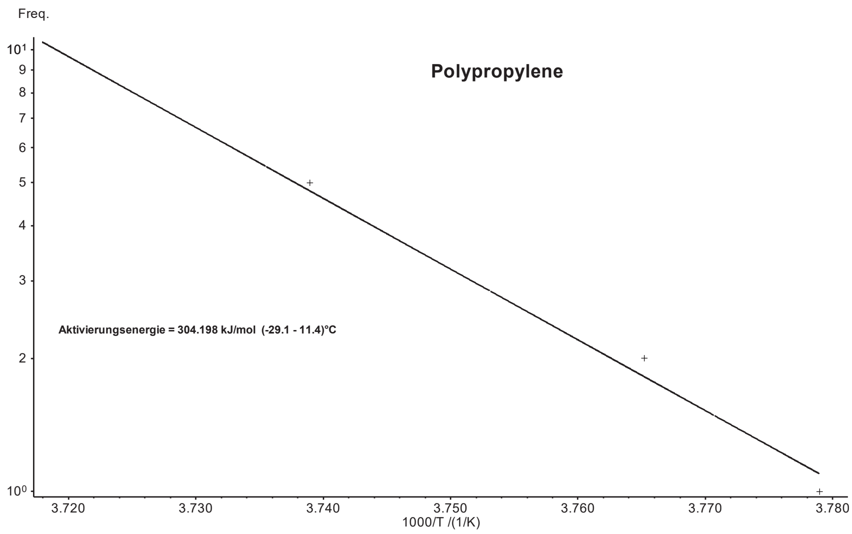

This "theory of free volume" is only valid above the E' onset of the transition where the movement of the polymer chains of the glue can occur. An isotherm (here at -5°C) above the transition temperature serves as a reference. Constants C1 and C2 of the WLF equation are automatically calculated when the so-called master curve is plotted. Here, the master curve shows the increase in storage modulus E´ over a range from 10^{-4} to 10^{-9} Hz.

The Arrhenius equation leads to an additional interpretation of the measurement data. The reciprocal temperature values of the maximum values for tan δ (unit: K) are plotted as a function of the logarithmic values of the frequency. The activation energy of the glass transition is subsequently calculated from the slope of the straight line. In this case, the Arrhenius equation provides an activation energy of 304 kJ/mol for the glass transition

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