

Rheological Properties of Polyvinylacetate: Creep Compliance and Viscosity

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Abstract: The dynamic viscoelastic properties of Polyvinylacetate with molecular weight 83000g/mol (PVA 83K) were determined by using a Rheometer operated in the dynamic mode and 8 mm parallel plate over a wide range of temperature as a function of frequency. The measurements were performed successively in the parallel plate geometry using 8 mm plate instead of 25 mm. The creep compliance and viscosity are measured and evaluated. The melt viscosity, η_0 is determined in this study for PVA 83K sample to be about 3.7×10^7 Pa.s.

Keywords: Melt viscosity of Polyvinylacetate, biodegradable plastic

1. INTRODUCTION

Rheology is concerned with the description of the mechanical properties of the various materials under the various deformation conditions. Polymer rheology is in its various aspects intimately entwined with molecular physics, continuum mechanics, and the processing of polymeric materials. At present, rheological investigations of polymers are processing at an enormously rapid rate, embracing a wide range of materials: biological objects, paste-like substances such as lubricants. The applied aspects of rheology are tied up with the development of new technological processes for the processing of plastics, elastomers and fibers [1]. The understanding of the relationship between the rheological properties of polymers and their molecular structure has considerably improved in the past few years with the interest of physicists in the matter and particularly with the development of molecular dynamics theories [2]. Besides, rheological measurements are used now as an analytical tool of polymer characterization [3].

In this work the rheological properties are investigated in details for a commercial PVA 83K.

2. EXPERIMENTAL SECTION

Polydisperse PVA 83K sample was prepared for the Rheological measurements. In the disc form with 8 mm diameter and 1 mm thickness by using a press mould without vacuum at 50°C under 10 bar for 20 min. The preparation steps and conditions are summarized as follows:

Approximately 0.1 g of the polymer is placed in a Teflon frame of dimensions 8 mm diameter and 1 mm thickness. This Teflon frame is introduced between two Teflon plates and positioned between two metallic plates in the mould. The sample is positioned on the lower plate followed by lowering the upper plate until just contact the upper Teflon plate. The sample is heated with heat rate 10°C/min. and pressed under 8-10 bar by lowering the upper piston for 20 min. The mould is cooled to 30 °C, followed by taking the sample out.

After preparation the sample for the measurement, the sample is placed on the lower plate of the ARES-Rheometer followed by lowering the stage until the sample just contacts the upper fixture completely. The ARES-Rheometer, consists of a test station, a furnace and liquid nitrogen controller. The test station contains the motor and transducer between which the sample to be tested is placed. The furnace is a forced convection environmental chamber that encloses the sample. The gas temperature is controlled by two resistive heaters and the nitrogen gaseous is used during testing at or above room temperature. If test temperatures are below room temperature, liquid nitrogen is used. The temperature of the oven is maintained by a control loop that is closed around a platinum resistive thermometer.

The normal force of the instrument should be kept around zero and the actual gap size is read electronically to be around 1 mm. The measuring program is adjusted to measure the sample over a wide range of temperature from 25 °C up to 150 °C as a function of frequencies in parallel plate geometry and dry nitrogen atmosphere. The strain was kept inside the linear regime in the whole frequency range. The strain is applied to the sample and the resulting stress is measured by the transducer. The stress signal generated by the sample separated into two components; an elastic part which is in the phase with strain and a viscous contribution which is 90° out of phase with the strain.

3. RESULTS AND DISCUSSION

The PVA83K sample was measured over a temperature range 25-150°C as a function of frequency. Different temperatures curves were shifted into single curve (Master curve) to a reference temperature T_0 (25 °C) by means of the time-temperature superposition principle as proposed by Williams, Landel and Ferry (WLF) [8].

Figure 1 shows creep compliance ($J(t)$). ($J(t)$ is approximately equal to the stress relaxation modulus, $G(t)$). $G(t)$ is defined as the stress divided by strain at constant deformation and is plotted versus time. The boundaries of the plateau are temperature-dependent. At short time the

corresponding region of the time scale is sometimes called glassy zone corresponds to the absence of any configurational rearrangements of the chain backbones. It is clear from Figure 1 that at long time $J(t)$ falls rapidly. In terms of mechanical models, this corresponds to the complete relaxation of all springs in an array. The region of time scale in which $J(t)$ falls rapidly is often called the flow or terminal zone.

If the viscoelastic (viscous and elastic at same time) behavior of the polymer is represented by a finite mechanical model, the decay of $G(t)$ must at the end become exponential, proportional to e^{-t/τ_i} where τ_i is the terminal relaxation time.

Figure 2 shows the dynamic viscosity as function of the frequency. The dynamic viscosity is related to the loss

modulus as, $\eta_0 = \lim_{\omega \rightarrow 0} \frac{G''(\omega)}{\omega}$ [4]. At low frequency

approaches the steady-flow viscosity, η_0 . As shown in Figure 2 at very low frequency the viscosity begins to be independent (η_0) on the frequency. η_0 is determined in this study for PVA 83K sample to be about 3.7×10^7 Pa.s. This value depends on the temperature and molecular weight of the polymer.

4. CONCLUSION

The rheological properties of PVA 83K are evaluated using an ARES Rheometer operated in the dynamic mode. The measurements were performed successively in 8 mm a parallel plate instead of 25 mm. The creep compliance and viscosity are measured and evaluated. The melt viscosity, η_0 is determined in this study for PVA 83K sample to be about 3.7×10^7 Pa.s.

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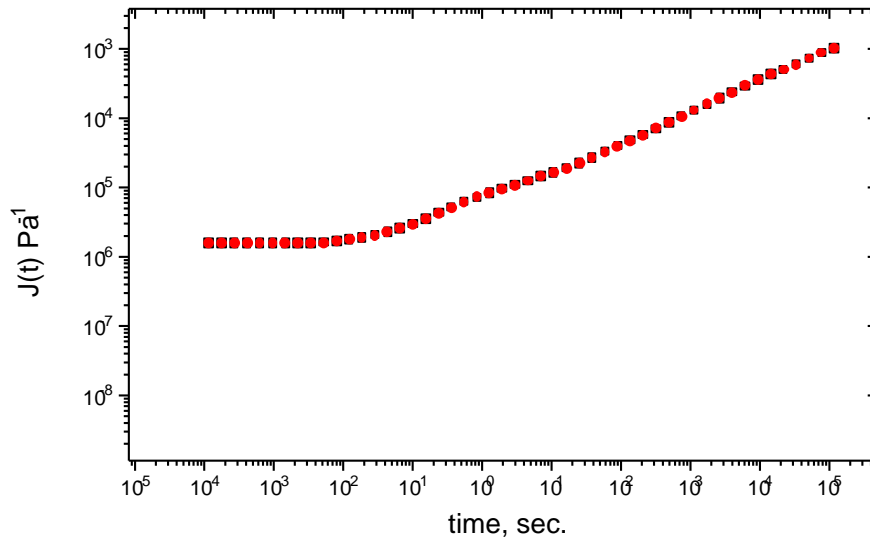


Figure 1: Master curve of the creep compliance for PVA 83K at $T_0 = 25\text{C}$.

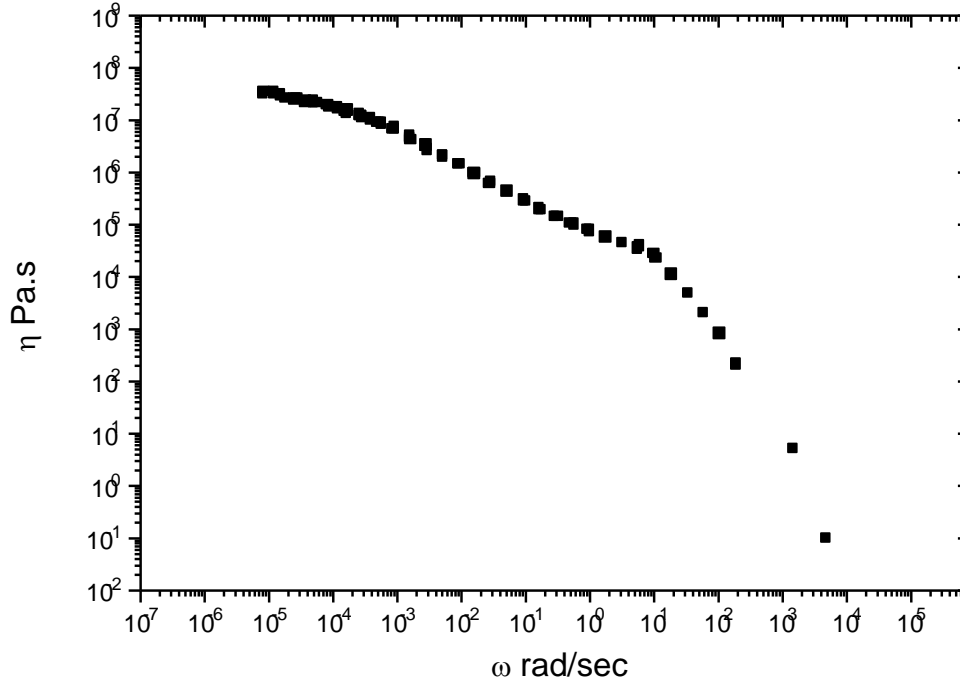


Figure 2: Plot of dynamic viscosity as a function of frequency for PVA 83K at $T_0 = 25\text{C}$.