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An Investigation on Moisture-dependent Viscoelasticity of Polymers: Experiments and Modeling

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ABSTRACT

Polymers are one of the most common engineering materials and their mechanical properties are of great importance. Most polymers are viscoelastic, and their time-dependent mechanical properties must be characterized and modeled for their efficient and safe use as structural components. Viscoelasticity of hydrophilic polymers can be significantly affected by moisture absorption; however, modeling the effect of moisture on the viscoelasticity of hydrophilic polymers has been limited in the literature. The purpose of the present study is to develop a model that can describe the effect of moisture on the viscoelasticity of hydrophilic polymers and validate the model against experimental results. The model is developed by considering the interaction between the molecular chains of hydrophilic polymers and absorbed water molecules. The water molecules exist in two forms within the polymer materials, free water and bound water. Free water can form water clusters and soften the polymer while bound water form bridge-like links between the polymer chains and stiffen the materials. Therefore, the absorbed moisture has both plasticization and anti-plasticization effects on the viscoelasticity of the polymers. Based on this consideration, a simple yet important modification was made to the well-known Reimschuessel model which only considers the plasticization effect. Combined with the widely used Burgers model, a modified Burgers-Reimschuessel model was proposed to describe the plasticization and anti-plasticization effect of moisture on the viscoelasticity of hydrophilic polymers. The proposed model was validated against the experimental results of four different polymeric materials obtained by Onogi et al., as well as against the experimental results for polylactic acid (PLA) obtained by the authors. PLA fibers were produced by melt-extrusion and conditioned in chambers with various relative humidities. Tensile creep tests were conducted, and the creep compliances were extracted to validate the proposed model. The proposed modified Burgers-Reimschuessel model agrees well with all experimental data and is a useful tool for describing the viscoelastic constitutive relation of hydrophilic polymers subject to moisture absorption.

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