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Rheology of Wood Flour Filled Poly(lactic acid)

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Abstract

This work investigates the rheological properties of wood flour filled poly(lactic acid) at typical processing temperatures, i.e. 155°C, 165°C and 175°C, using a parallel plate rheometer run in oscillatory mode. Materials with three different filler loading levels (10, 20 and 30% wt.) are characterized together with the neat matrix. Considering the complex viscosity curves, it is found that a single master curve can be obtained, which allows to predict the viscosity of the material at any filler loading level and any temperature that are included in the interval tested.

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Keywords: Wood Polymer Composites; Poly(lactic acid); Rheology

1. Introduction

The increasing perceived importance of environmental issues has driven a remarkable collective interest towards plastics that are biodegradable [1,2]. The most common of such materials is poly(lactic acid) or PLA. The main drawback of this material is its cost, which is much higher than oil based commodity thermoplastics. The use of natural fibres as fillers offers the possibility of reducing material cost and, in some cases, also to increase mechanical properties, without altering its environmental sustainability character [3].

On the other hand, filling a thermoplastic polymer with natural fibres gives rise to a number of drawbacks. For instance, material viscosity increases and, due to localized viscous heating during processing, material degradation is more likely to occur [4]. This is especially true for PLA that is very sensitive to heat induced hydrolytic

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degradation [5]. Therefore, it is very important to characterize the viscosity of natural fibre filled PLA and optimize processing conditions in order to allow good quality of the final product.

In this work a commercially available PLA has been filled with wood fibers at three filler loading levels. From these compounds, rheometry testing at typical processing temperatures has been performed using a parallel plate rheometer in oscillatory mode to measure complex viscosity. For completeness, pure matrix samples have also been characterized. A single master curve is obtained that can reasonably predict the complex viscosity of molten composites within temperature and filler volume fraction range that has been investigated.

Nomenclature

η^*	complex viscosity	T, T_0	current and reference temperature
G', G''	complex moduli: storage and loss	a_T	thermal shift factor
ω	frequency	ϕ	volumetric concentration
η_0, λ, c, n	Carreau-Yasuda parameters	ϕ_m, m	Krieger Dougherty parameters
C_1, C_2	Williams Landel Ferry parameters	b_ϕ	concentration shift factor

2. Materials and methods

2.1. Materials

The matrix is a commercial poly(lactid acid) named NEVIBIO PLA 0509 purchased from Nevicolor S.p.A, Luzzara (RE), Italy. Its melting temperature is 150°C and has a density of 1.22 g/cm^3 at 23°C. The natural filler is wood flour from spruce, with a bulk density of 1.4 g/cm^3. It has been purchased from JELU, Rosenberg, Germany under the commercial name of JELUXYL HW 50/100.

All rheometry specimens are in the form of 25 mm diameter discs. Neat PLA samples have been punch cut from a 1.5 mm thick slab obtained by compression molding at 180°C with a pressure of 70 bar. The composites contain 10, 20 and 30 wt.%. wood fibers and have been prepared as follows: the filler has been compounded together with PLA using a twin screw co-rotating extruder to obtain the 30 wt.% composite. The fiber concentration has been imposed through a gravimetric feeder. The relevant processing parameters are: flat temperature extrusion profile at 155°C and screw speed of 100 RPM and have been chosen to prevent thermal and hydrolytic degradation inside the extruder. Wood fibers and PLA have been dried at 85°C for 24 hours before compounding. The compound pellets has been further processed by single screw extrusion to obtain 50 mm x 2 mm slabs. During this second extrusion, the 30 wt.% compound has also been diluted with the neat matrix in the hopper, so that composites at 10 wt.% and 20 wt.% wood fiber content have been obtained in addition to the original 30 wt.%. Again a flat 155°C temperature profile has been imposed. The composite specimens have been finally punch cut from the extruded slabs.

After processing, some of the specimens have been dissolved in chloroform to measure wood fibers geometric features. These are reported in Tab. 1: the filler is in the form of short fibers (aspect ratio less than 10). Possibly, the fibers could have been shortened during compounding and extrusion.

Table 1. Wood fibers geometric features. Values in parentheses represent standard deviations

Length (μm)	Diameter (μm)	Length/Diameter
986.1 (102.6)	311.2 (50.42)	3.2 (0.33)