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ORIGINAL PAPER

Melt rheology of linear and long-chain branched polypropylene blends

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Abstract The miscibility of linear polypropylene (L-PP) and long-chain branched polypropylene (LCB-PP) blends was studied in relation to the rheological behavior in shearing and elongational deformations of the blends. The rheological properties of four commercial L-PPs with different molecular weights were studied by adding 10, 25, 50, and 75 wt% of LCB-PP to L-PP. The linear viscoelastic properties such as complex viscosity and weighted relaxation spectrum were determined as functions of LCB-PP content. According to the obtained rheological data, the LCB-PP showed a higher zero-shear viscosity and a longer relaxation time than the L-PPs. The linear viscoelastic properties showed an increase in the molecular weight and branched content of the L-PP with a reduction in miscibility. Furthermore, good predictions of linear viscoelastic properties for miscible and immiscible blends were achieved by applying the Palierne model. In uniaxial elongational tests, the L-PP showed no strain hardening behavior. By contrast, the addition of 10 wt% LCB-PP to L-PP resulted in strain hardening behavior at all strain rates. Hence, the strain hardening behavior of the blends was enhanced with LCB-PP content. The elongational viscosity data of the L-PP and LCB-PP and their blends were studied by employing the Molecular Stress Function (MSF) model which could predict the strain hardening behavior of the blends.

Keywords Polypropylene · Long-chain branched · Rheology · Miscibility · Molecular Stress Function

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List of symbols

G'	Elastic modulus
G''	Loss modulus
G^*	Complex modulus
η^+	Complex viscosity
ω	Frequency
LCB-PP	Long-chain branched polypropylene
L-PP	Linear polypropylene
η_0	Zero-shear viscosity
$H(\lambda)$	Continuous spectrum function
g_i	Relaxation modulus
λ_i	Relaxation time
MSF	Molecular Stress Function
ϕ_β	Weightfraction of branched component
α	Interfacial tension
R_v	Average radius of droplets
a	Diameter of tube segment
$\sigma(t)$	Extra stress tensor
f	Molecular Stress Function
S_{DE}^{IA}	Strain measure of the Doi-Edwards model
S_{DE}	Second-order orientation tensor
$\mathbf{u}'$	Unit vector
u'	Length of unit vector
η_E^+	Transient elongational viscosity

Introduction

Isotactic polypropylene is one of the leading and fast growing thermoplastic polymers in the world due to its desirable and beneficial properties such as low density, high melting point, high chemical resistance, and low cost. However, commercial polypropylene produced by Ziegler–Natta or metallocene catalysts has linear chains and a relatively narrow molecular weight distribution [1–3]. Linear