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Material Behaviour

Melt rheology and extrudate swell of low-density polyethylene/ethylene–octene copolymer blends

Rapeephun Dangtungee[a,1], Satyen S. Desai[b], Supawan Tantayanon[c], Pitt Supaphol[a,*]

[a]The Petroleum and Petrochemical College, Chulalongkorn University, Bangkok 10330, Thailand
[b]Petrochemistry and Polymer Science Graduate Program, Chulalongkorn University, Bangkok 10330, Thailand
[c]Department of Chemistry, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand

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Abstract

The melt rheological and extrudate swelling behavior of neat low-density polyethylene (LDPE) and blends of LDPE and ethylene–octene copolymer (EOC) was investigated using capillary rheometry at $185.0 \pm 0.5\,^{\circ}$C. Dies having different length-to-inner diameter (L/D) ratios were used (i.e., 5/1, 10/11, 10/2, and 30/2 mm/mm, respectively). For a given sample material, the real shear stress was observed to increase with increasing real shear rate, and, for a given real shear rate, the real shear stress was generally observed to increase with the addition and increasing amount of EOC. All of the sample materials exhibited the shear-thinning behavior. Both the tensile stress and the elongational viscosity were found to decrease with increasing elongational rate. Generally, both the tensile stress and the elongational viscosity increased with the addtion and increasing amount of EOC, with an exception for the 85/15 and 80/20 LDPE/EOC blends which exhibited a reversed order. Lastly, the extent of extrudate swelling of the sample materials in the small dies (i.e., inner diameter = 1 mm) was greater than that in the larger ones (i.e., inner diameter = 2 mm) and the use of a longer die also helped suppress the extent of the extrudate swelling.

Keywords: Capillary rheometry; Melt extrusion; Shear viscosity; Elongational viscosity; Extrudate swell

1. Introduction

Rheological behavior of polymeric melts is an important aspect to understand the flow behavior of the materials during processing, which, in turn, has a strong influence on the final properties of the products after solidification. Studies related to rheological behavior of pure polymeric melts have been well documented, while such studies on molten polymer blends are quite limited, but indispensably important [1]. Blend properties depends strongly on characteristics of each pure component [2]. Capillary rheometry is the most common technique used to determine deformation of polymeric melts under shear flow [3]. It can also be used to evaluate the elastic effect such as die or extrudate swell behavior

*Corresponding author. Tel.: +66 2218 4131; fax: +66 2215 4459.
E-mail address: pitt.s@chula.ac.th (P. Supaphol).
[1]On study leave for a doctoral degree from the Faculty of Applied Science, Kingmongkut's Institute of Technology North Bangkok, Bangkok 10800, Thailand.

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[4]. A number of studies reported the extrudate swell as a function of the length-to-diameter (L/D) ratio of the die, the pressure drop across the die, entry angle of the die, shear stress, shear rate, and so on [5–8].

Elastomeric polyolefins are suitable materials for foam extrusion, e.g., profile extrusion of tubes and hoses, due to their excellent properties such as excellent toughness, good flexibility, and good transparency [9]. Due to its longest branching units among the various elastomeric polyolefins, ethylene–octene copolymer (EOC) exhibits the lowest glass transition temperature (T_g) and the least apparent degree of crystallinity, hence the greatest toughening contribution, in comparison with another elastomeric polyolefins, such as ethylene–propylene or ethylene–butadiene copolymer, at a similar comonomeric content [10].

Moly et al. [11] studied the elastic and extrudate swell behavior of molten linear low-density polyethylene (LLDPE)/ethylene–vinyl acetate (EVA) blends and reported that the extrudate swell increased with increasing shear rate and elastomer content, and that a critical shear rate was observed at the onset of the melt fracture. Liang [12] investigated the elastic behavior of low-density polyethylene (LDPE)/LLDPE blends by capillary extrusion and found that the extrudate swell increased linearly with increasing wall shear stress and the entry pressure drop and decreased with increasing L/D ratio of the die and that a maximum in the extrudate swell was observed at a 50:50 w/w blend ratio. McNally et al. [10] showed that the viscosity values of isotactic polypropylene (iPP)/EOC blends followed the prediction by the log-additivity principle and the blends showed partial miscibility only when the EOC content was 10 wt% or less. Silva et al. [1] studied rheological behavior of iPP/EOC and iPP/ethylene–propylene–diene copolymer (EPDM) blends and showed that, at high shear rates, both types of blends exhibited similar rheological behavior. Nayak et al. [13] studied the rheological behavior of both neat and precipitated silica-filled EOC vulcanizates with addition of a blowing agent and showed that incorporation of the blowing agent led to decreased shear-thinning behavior, resulting in an increase in the power-law index.

The main objective of the present contribution was to investigate the effect of compositional ratio of blends of low-density polyethylene (LDPE) and ethylene–octene copolymer (EOC) on melt rheology and extrudate swell behavior using capillary rheometry. The LDPE/EOC blends investigated in this work were formulated for a foam-sheet extrusion line.

2. Experimental

2.1. Materials

A general purpose grade of LDPE (JJ 4342) was supplied by Thai Petrochemical Industry Plc. (Thailand). Some specifications of the resin are as follows: MFR (2.16 kg at 190 °C) = 5.5 g/10 min, density = 0.920 g cm^{-3}, tensile strength at yield = 11 MPa, ultimate elongation = 600%, Vicat softening temperature = 95 °C. Ethylene–octene copolymer (EOC; Engage® 8450) with the comonomer content of 17 wt% was supplied by Dupont-Dow Elastomers L.L.C (USA). Some specifications of the resin are as follows: MFR (2.16 kg at 190 °C) = 3.0 g/10 min, density = 0.902 g cm^{-3}, and ultimate tensile strength (508 mm min^{-1}) = 24.8 MPa.

2.2. Blend preparation

Dry-blends of LDPE and EOC with different contents of EOC (i.e. 15, 20, and 25 wt%) were prepared by mixing the resins in a tumble mixer for 20 min. It should be noted that 0.5 wt% of talcum and 0.98 wt% of a paraffin wax were added into the formations. Talcum was used as a nucleating agent

Table 1
Formulations of the blends

Compositions (wt%)	Neat LDPE	85/15 LDPE/EOC	80/20 LDPE/EOC	75/25 LDPE/EOC
LDPE	100	85	80	75
EOC elastomer	0	15	20	25
Talc	0.50	0.50	0.50	0.50
Wax	0.98	0.98	0.98	0.98