Flow Curves and Extrudate Swell Behavior of Co-Extrudates of PS with LLDPE or ABS

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Abstract

Rheological properties and extrudate swelling ratio of LLDPE/PS and ABS/PS co-extrusion systems in a single screw extruder for different die temperatures and core sizes were examined. The flow properties for both co-extrusion systems were similar to those for PS alone. The presence of either LLDPE or ABS as inner layer promoted the swelling ratio and die temperature effect of the PS extrudate. The extrudate swell of PS increased with increasing the initial core from 2.5 to 5.0 mm.

Keywords: Co-extrusion; polystyrene melt; rheology; swelling

1. Introduction

Co-extrusion is the process of extruding two or more materials through a single die with two or more orifices arranged so that the polymer extrudates merge together into a laminar structure before cooling. When co-extruding into a capillary die, swelling of the extrudate is used to determine qualities and dimensions of the extruded product [1], and to allow engineers to design the processing elements (screw, barrel and die). Recently, flow properties and flow patterns of co-extrudates have been carried out extensively [2-3]. In experimental studies, the flow patterns of the melt layers flowing in the die have been found to be very complex as a result of differences in melt viscosity of the extruded layers across the flow chanel [3-4]. The swelling ratio of the extrudate across the die diameter was not uniform [5-6], the swelling ratio decreasing as the reduced radius (r/R ratio) increased. This article studies the rheological properties and extrudate swelling ratio of co-extrusions of LLDPE/PS and ABS/PS systems in a single screw extruder for different die temperatures and core sizes.

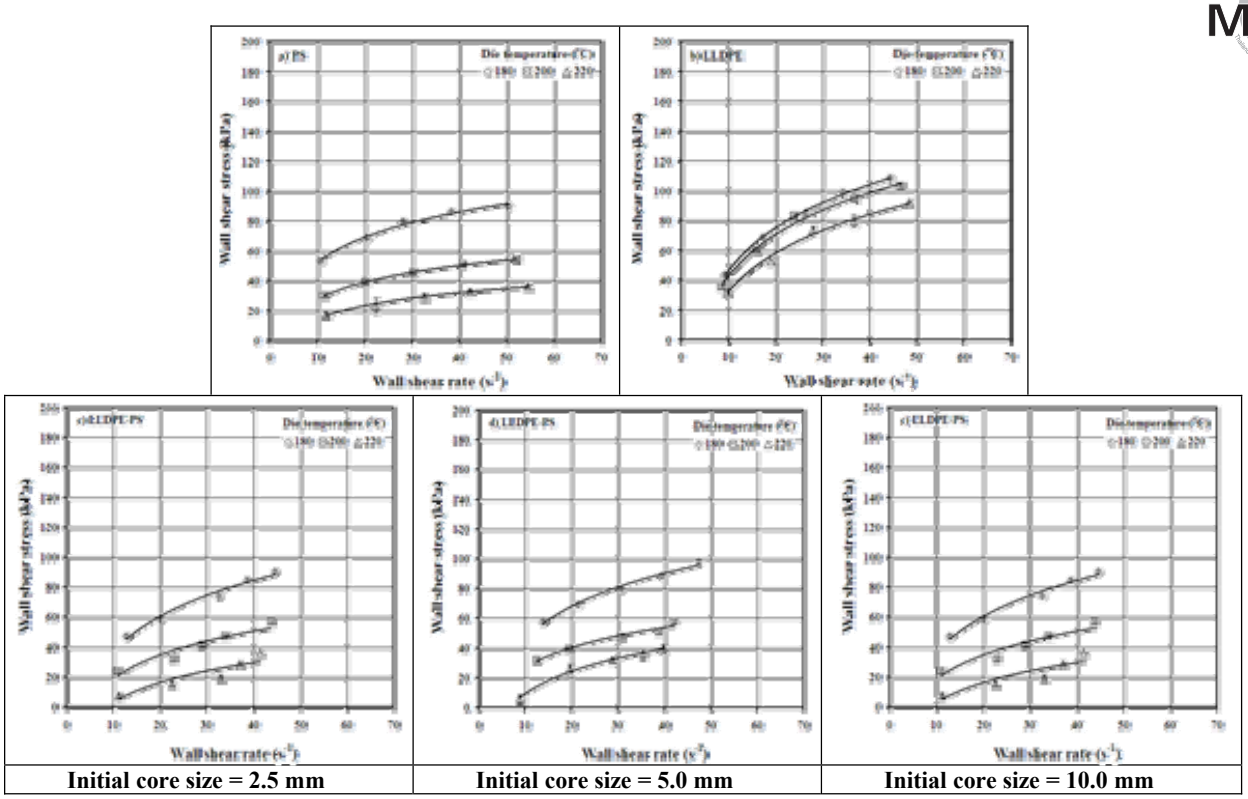
2. Experimental

2.1 Raw materials: Polystyrene (PS, Styron 656D267; Siam Polystyrene Co., Ltd, BKK, Thailand), Linear low-density polyethylene (LLDPE, L2009F; Thai Polyethylene Co., Ltd BKK, Thailand), Acrylonitrile Butadiene Styrene copolymer (ABS, PA-747S; Global Connections Co., Ltd, BKK, Thailand), were used for this study.

2.2 Co-extrusion, flow curves and extrudate swell ratio: In this work, the PS melt was assigned to be the outer layer, and either the LLDPE or ABS melt was assigned to be extruded as the core layer. Parallel Co-extrusion Technique (PCT) originally developed by Intawong and Sombatsompop [5-6] were used by connecting with a single screw extruder. The principle of the PCT involved the extruding of core melt into the outer melt in the barrel of the screw extruder-PCT equipment. Plots of shear stress against shear rate of the three thermoplastics and its co-extrudates were established. The barrel dimensions for the PCT were 40mm in diameter and 165 mm long, and a borosilicate die having 5mm in diameter and 64mm in length at the bottom of the barrel. The swelling ratio of the polymer melt was determined by the ratio of the diameters of the extrudate to that of the die in the fully swollen state. The effects of die temperature, screw speed, and initial core sizes were studied.

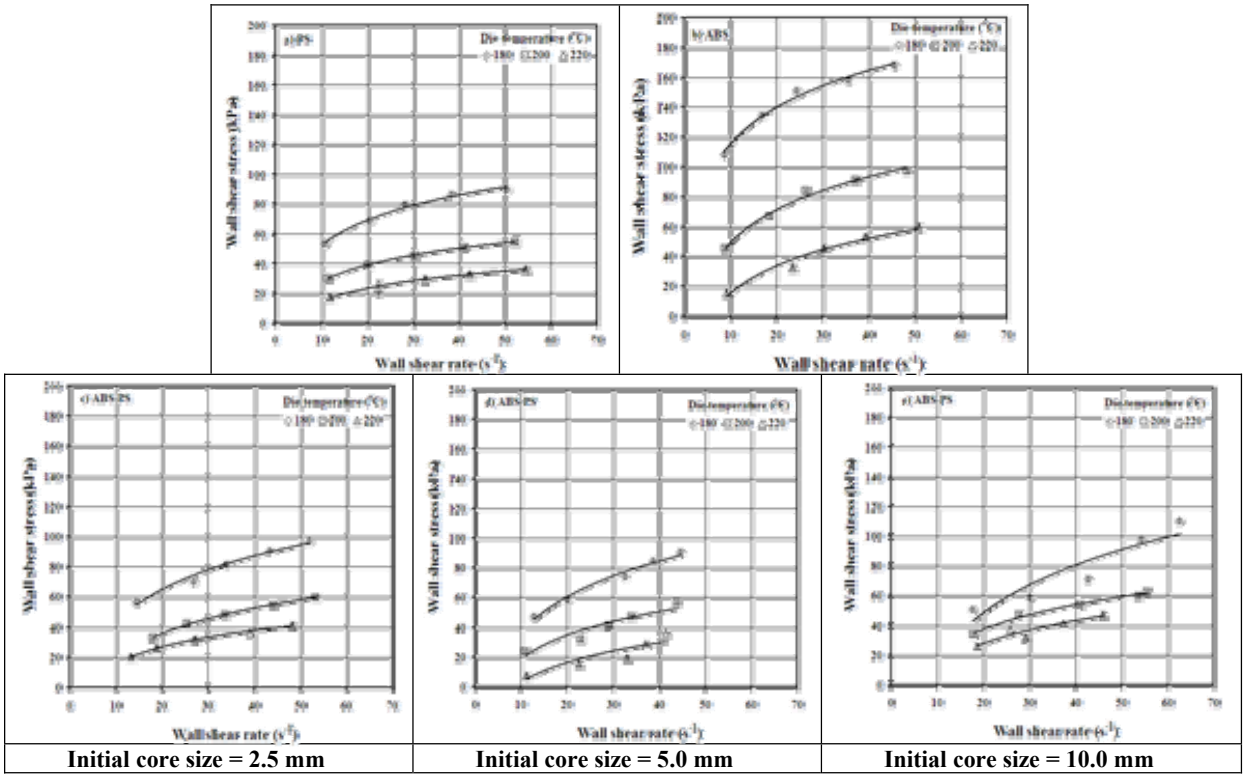
3. Results and Discussion

Figures 1 and 2 show flow curves of PS, LLDPE and LLDPE/PS co-extrudates and PS, ABS and ABS/PS co-extrudates for different die temperatures and initial core sizes. Each melt exhibited a psuedoplastic non-Newtonain character. For a given shear rate, increasing the die temperature the shear stress decreased. The flow curves for the LLDPE/PS and ABS/PS co-extrudates for different initial core sizes and die temperatures were very similar to those of PS, suggesting that the flow properties of the co-extrudates were dominant by PS melt although the LLDPE or ABS melt had occupied up to one-fourth of the extrudate cross-section (i.e., 10mm initial core size). **Figures 3 and 4** show the co-extrudate swell ratio of PS, LLDPE and LLDPE/PS co-extrudates, and PS, ABS and ABS/PS co-extrudates for different die temperatures and core sizes, respectively. The maximum swells for LLDPE/PS and ABS/PS at 180°C were 1.67 and 1.65 whereas the maximum swell for PS was 1.47, suggesting that the addition of either LLDPE or ABS promoted the PS swelling. It was found that the extrudate swell ratios for all cases decreased with increasing shear rate, the decreasing trend being greater than that for PS. This was due to the shear heating effect in this complex co-extrusion system[5]. This involved the lower extrudate swell ratio of LLDPE and ABS melts. The effect of die temperature on the co-extrudate swell became more significant than that for PS melt alone. As the initial core size was increased from 2.5 to 5.0 mm, the overall extrudate swell ratio appeared to increase as compared to that for the PS melt alone, but tended to decrease when the initial core size had reached 10mm. The increased swelling may be related to the local



Initial core size = 2.5 mm	Initial core size = 5.0 mm	Initial core size = 10.0 mm

Figures 1 The flow curves of PS, LLDPE and LLDPE/PS co-extrudates



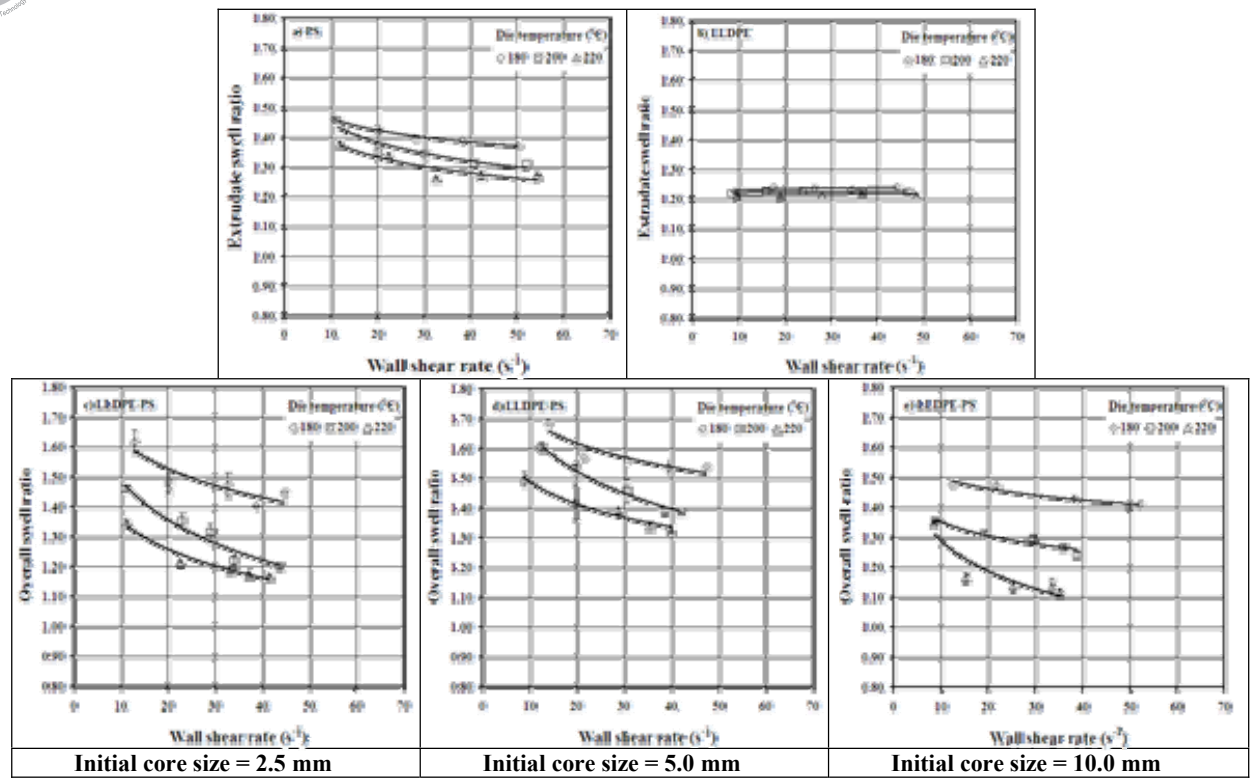
Initial core size = 2.5 mm	Initial core size = 5.0 mm	Initial core size = 10.0 mm

Figures 2 The flow curves of PS, ABS and ABS/PS co-extrudates

Swell of LLDPE or ABS at the centre position of the extrudate. Previous works[5-6] suggested that the swelling ratio at the die centre was extremely high. However, when the initial core size was increased the swelling ratio of the co-extrudates decreased, due to the proportional increases of lower swelling polymers (LLDPE and ABS in this case) in the co-extrudates.

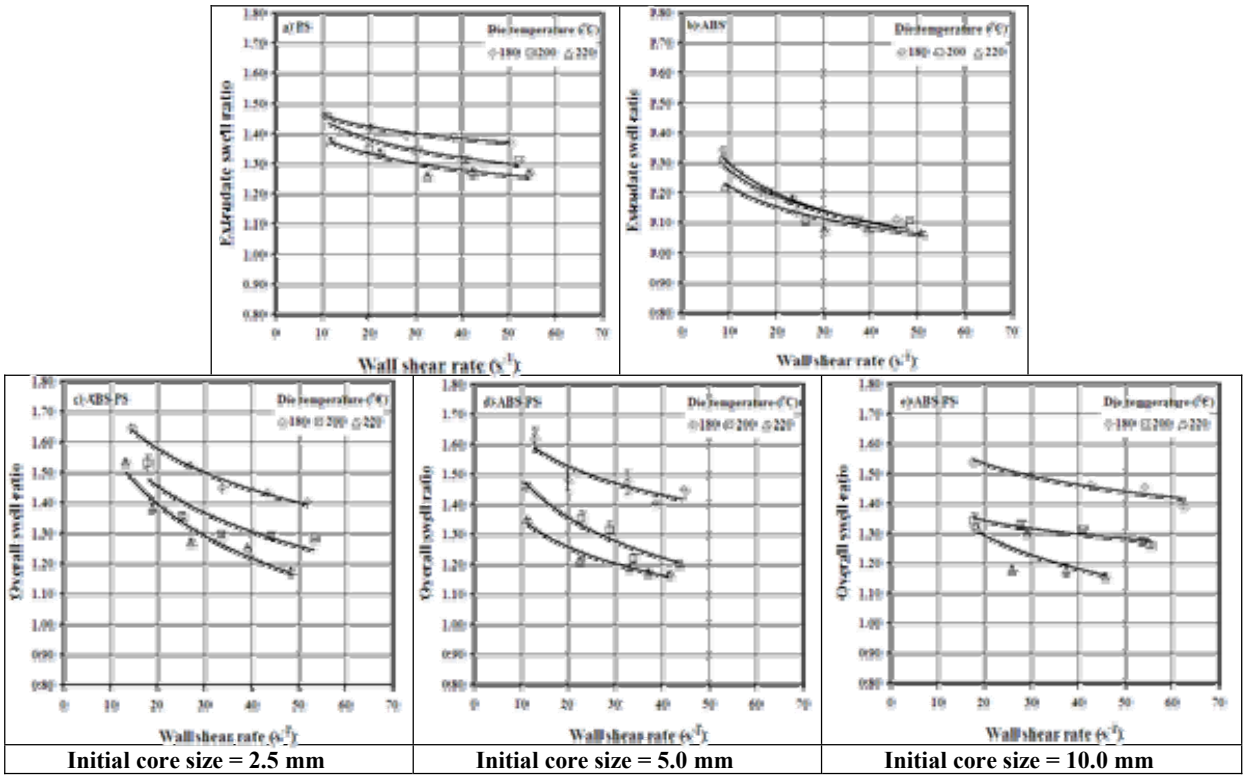
4. Conclusion

The flow curves for the LLDPE/PS and ABS/PS co-extrudates were controlled by the PS layer. The addition of either LLDPE or ABS promoted the swelling ratio and the temperature effect in the PS extrudate. As the initial core size was increased from 2.5 to 5.0 mm, the overall extrudate swell ratio increased as compared to that for the PS melt alone.



Initial core size = 2.5 mm	Initial core size = 5.0 mm	Initial core size = 10.0 mm

Figure 3 The co-extrudate swell ratio of PS, LLDPE and LLDPE/PS co-extrudates



Initial core size = 2.5 mm	Initial core size = 5.0 mm	Initial core size = 10.0 mm

Figure 4 the co-extrudate swell ratio of PS, ABS and LLDPE/ABS co-extrudates

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