Viscoelastic Simulations of the Effect of Strain Hardening on Interfacial Roughness during Two-layer Coextrusion

K. Takeda[1], S. K. Sukumaran[1], M. Sugimoto[1]

[1] Graduate School of Organic Materials Science, Yamagata University, 4-3-16, Jonan, Yamagata, Japan (kei@yz.yamagata-u.ac.jp)

Multilayer layer films offering a combination of characteristics such as gas barrier, moisture resistance, and stiffness can be efficiently produced using coextrusion. During coextrusion, roughness has been observed at the interfaces between the layers, the film surface, or both. Depending on their type, the instabilities underlying the roughness have been attributed to various factors. Experimentally, strain hardening of the polymer comprising the minor layer (i.e., lower flow rate) has emerged as a crucial factor governing certain types of instability[1-3], but the underlying mechanisms remain unclear.

To explore the flow characteristics in greater depth, we performed three-dimensional finite element viscoelastic simulations of two-layer coextrusion using ANSYS Polyflow. The Phan–Thien Tanner constitutive equation[4] was used to describe the nonlinear viscoelasticity of the polymer melts. The 3D coextrusion die cross-section is shown in Fig. 1. We focused on the flow characteristics near the confluence of the two layers. Several combinations (with/without strain hardening) and several flow rates of the minor/major layers were investigated.

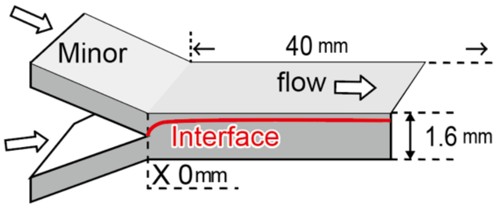

Figure 1: Schematic of coextrusion die cross-section.

In Fig. 2, the stretch rate, $\dot{\varepsilon}$, (left) and the generalized normal stress difference, N_1, (right) are shown as a function of the distance from the confluence point, X, for a flow rate ratio of 1:5 (minor: major layer). Simulations were performed for four combinations: 1. SH/SH, 2. NoSH/NoSH, 3. SH/NoSH, 4. NoSH/SH. Here "SH" indicated that the material exhibits strain hardening while "NoSH" indicated the absence of strain hardening. From Fig. 2, the N_1 exhibits a rapid increase followed by a decrease just downstream from the confluence point, but only if the strain hardening material comprised the minor layer. Interestingly, the increase was larger when the major layer was composed of a material that does not strain harden. The $\dot{\varepsilon}$, on the other hand, exhibited a rapid increase only for the SH/No combination. The relevance of these findings will be discussed during the presentation.

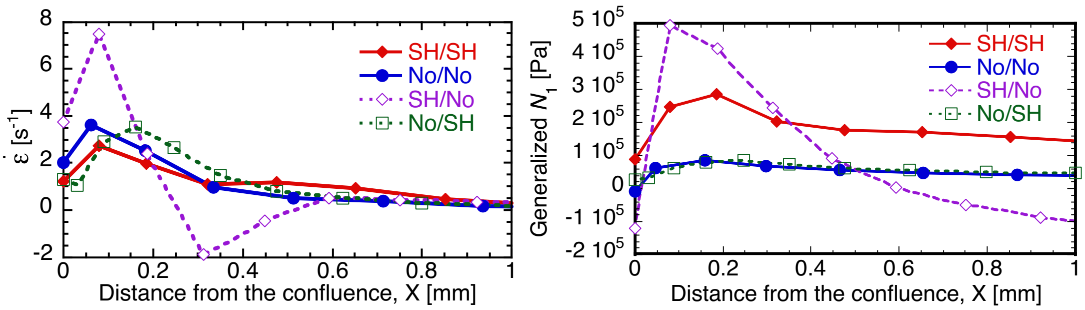

Figure 2: (left) Stretch rate, $\dot{\varepsilon}$, and (right) generalized normal stress difference, N_1, at the interface as a function of distance from the confluence point. Here "SH" indicates that the material exhibits strain hardening while "NoSH" indicates that the lack of strain hardening.

[1] C. Tzoganakis and J. Perdikoulias, *Polym. Eng. Sci.*, **40**, 1056 (2000).
[2] M. Zatloukal *et al.*, *Polym. Eng. Sci.*, **42**, 1520, (2002).
[3] M. T. Martyn *et al.*, *J Non-Newt Fluid Mech*, **156,** 150 (2009).
[4] N. Phan-Thien and R.I. Tanner, *J. Non-Newt. Fluid Mech.*, **2**, 353 (1977).