CHAPTER I

INTRODUCTION

Polymer blending is a simple and economical method for producing a new polymer with various desired properties. Most of polymer blends tend to be immiscible blends, which consist of the major (matrix) phase and the minor (disperse or droplet) phase. To improve mechanical or physical properties of immiscible polymer blends, the morphology of the droplet phase during a blending process, in which the two main mechanisms of shear and elongational strains generally occurring, is important. The properties of immiscible blends are controlled directly by the droplet size and distribution, which is the result some elementary steps in the mixing process. Those elementary steps are deformation, relaxation, and breakup of the drop phase in flow fields. Moreover, the behavior of droplet phase can be affected by processing conditions such as shear rate and rheological properties of components such as viscosity of the drop phase, viscosity of the matrix phase, the viscosity ratio of the blend, the interfacial tension, etc, and for common polymers, elasticity is also important. Although mostly commercial blends are concentrated and consisting of drops of various sizes, it is also important to understand the behavior of a single drop first as fundamental knowledge.

The pioneering work was by Taylor in 1932 who studied the steady state deformation and breakup of a Newtonian drop. For small deformation, he found that the drop deformation is governed by two dimensionless parameters, the first is viscosity ratio;

$$\eta_r = \frac{\eta_d}{\eta_m}$$

(1.1)

where d and m stand for disperse phase and matrix phase, respectively. Another parameter is the capillary number: the ratio of the matrix viscosity to the interfacial tension, which is defined as

$$Ca = \frac{\eta_m \dot{\gamma} D_0}{2\Gamma}$$

(1.2)

where γ is the shear rate, D_0 is the initial radius of the droplet, and Γ is the interfacial tension.

Moreover, Taylor revealed that at small Ca, the drop is gradually deformed to a steady state ellipsoid shape, whose the major axis orients at the constant angle, 45° with the flow direction. He also defined the deformation parameter (Def) as a function of capillary number and the viscosity ratio:

$$Def \equiv \frac{a-b}{a+b} = Ca\frac{19\eta_r + 16}{16\eta_r + 16} \tag{1.3}$$

where a is the major axis and b is the minor axis of the deformed drop as shown in Fig. 1.1.
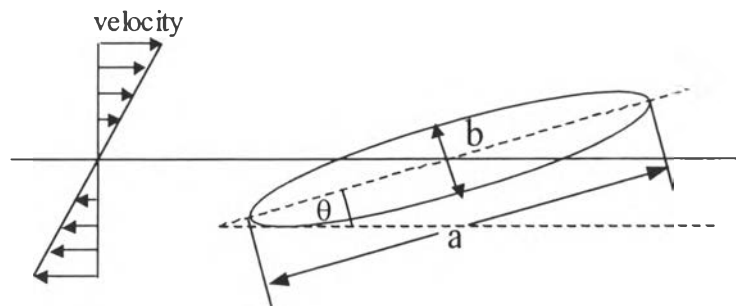

Figure 1.1 Schematic representation of drop deformation in shear flow

Taylor also predicted that the droplet breakup should occur when the viscous force that deforms the drop overwhelms the interfacial tension that resists the deformation. This occurs when the deformation parameter (Def) is approximately 0.5. He revealed the two major exceptions: when the viscosity ratio is low (less than 0.05), the droplets deform greatly before they break, and when the viscosity ratio is larger than 4, the deformation remains modest despite undergoing high capillary number, and no breakup is observed (Grace 1982) These results show that for Newtonian fluids, droplet deformation and breakup is strongly influenced by viscosity ratio, a result that emphasizes the importance of controlling this parameter carefully in any attempt to study the effects of other factors, such as viscoelasticity, on droplet deformation and breakup.

However, most of polymers are viscoelastic materials, and the elasticity should be an important factor to induce the behaviors of an isolated drop under flow fields. Drop widening in vorticity direction was first observed in high viscoelastic

matrix by Levitt and Macosko (1996). Many previous works mentioned that the high elasticity of the disperse phase resulted in the elongation in the vorticity direction [Hobbie and Migler (1999), Migler (2000), Mighri and Huneault (2001)]. When the critical point is reached the elastic droplet will break and there are some satellite drops in between [Mighri *et al.* (1998), Mighri and Huneault (2001)].

In our work reported here, we take a further step towards understanding the behavior of commercial blends by using elastic polymer melts for both the droplet phase and the matrix phase. To neutralize any effect of variations in the viscosity ratio, we choose pairs of commercial polymers whose viscosity ratios remain relatively constant near unity when shear rate is varied. Using a flow cell mounted on an optical microscope, we observe the deformations of isolated droplets in steady shear flow between parallel disks. By varying droplet size and shear rate, the effects of capillary number and elasticity are isolated and investigated at fixed viscosity ratio very near unity.