CHAPTER II
LITERATURE REVIEW

Levitt and Macosko (1996) studied the influence of normal stress difference on polymer drop deformation by using two transparent counter-rotating parallel disks. They utilized polypropylene of varying viscosity and elasticity as drop phases and polystyrene as a matrix phase, all drops were sheared at approximately 1 s^{-1}. They observed the transition from a drop to a sheet and contracted from a sheet to a fiber due to interfacial tension. They proposed that the width of the flattened drops depends on the difference in elasticities between the matrix and the drop, and it is proportional to the second normal stress differences of the two phases.

Stefano Guido and Macro Villone (1997) studied the three-dimensional deformation of an isolated drop in an immiscible blend undergoing simple shear flow by using a parallel-plate apparatus. This work shows that the shape of a deformed drop was virtually ellipsoidal with three different axes up to relatively large values of deformation. Moreover, they found a good agreement of experimental drop shape and numerical simulations (by Pozrikidis).

F. Mighri, A. Ajji and P.J. Carreau (1997) studied the effect of elasticity on drop deformation in elongational flow, which was provided from a transparent channel of plexiglas with a converging and diverging cross sectional channel. They revealed that the deformation decreased with rising elasticity of drop phase, and it increased with increasing matrix elasticity. However, the deformation seemed to be controlled by the drop elasticity. They defined the elasticity ratio, k', as the ratio of the Maxwell relaxation time (λ) of the drop phase to that of the matrix phase, where $\lambda=N_1/2\eta\gamma^2$. They concluded that for k'<0.2, the matrix elasticity had more effect on the drop deformation than the drop elasticity, and for k'>0.2, the drop deformation was more affected by the drop elasticity.

In 1998, Mighri *et al.* worked on the influence of elastic properties on drop deformation and the critical breakup condition of a single drop in shear flow by using two transparent parallel disks mounted on a R-18 Weissenberg rheogoniometer. The polymer, used as matrix phase, was prepared from 92% maltose syrup, up to 8%

distilled water and varied PAA (0-0.1%) as the elastic substance. In the similar fashion, the drop fluids consisted of 93%PIB, up to 7%Kerosene, and 0-1.2% PIB. A significant difference in the mechanism of the drop deformation between the Newtonian and the elastic systems was that the deformed elastic drop looked like a spheroid with slightly sharp edges while the Newtonian drop conserved its curved ends. They inspected that the deformation, the critical shear rate, and breakup time rised with increasing elasticity ratio between the drop and the matrix. Conspicuously, the breakup process resulted in a series of alternating large and small drops (satellites). Moreover, they found that for the low elasticity ratio, $k' < 4$, the critical capillary number increased rapidly with rising k', and it reached a level of about 1.75 at high elasticity ratio, $k' > 4$. In other words, the drop resistance to deformation and breakup increased with rising elasticity ratio.

Yamane *et al.* (1998) observed the deformation and recovery of a polyisobutylene droplet in a PDMS matrix after application of a step shear strain by a stereo-optical microscope with still and video camera, and the blend was subjected to shear between two parallel glass plates. This work illustrated that the magnitude of applied strain remarkably affected the droplet shape and recovery time. In addition, just after applying a large strain a droplet deformed to a flat ellipsoid, and then into a rodlike, a dumbbell, to an ellipsoid of revolution, and lastly to a sphere.

Vassilios and Patrick (1998) studied the deformation and breakup mechanisms of single drops during shear with a cone-and-plate rheometer performed on a rheo-optical system. They mainly observed the unsteady deformation and breakup processes of drops characterized by large capillary numbers. They found that the end pinching mechanism occurred at a specific strain, which included the initial drop size and the applied shear rate. Moreover, capillary instabilities developed when the critical thread diameter, inversely proportional to the applied shear rate and independent of the initial drop diameter, was observed. The initial drop diameter, the applied shear rate, and the critical thread diameter were found to affect the time necessary for the total rupture of a thread.

Hobbie and Migler (1999) studied dilute emulsions of viscoelastic droplets in viscoelastic matrices at high shear rate and observed elongation of the droplet in the vorticity direction at $\dot{\gamma} \sim 280\ s^{-1}$ for $\eta_r = 1.8$. By extrapolating of data at high shear rates to lower rates, they obtained critical capillary numbers for droplet vorticity alignment of around 53, 13, and 11 for viscosity ratios, η_r, of 1.8, 22, and 240, respectively.

Migler (2000) observed the deformation of highly elastic droplets (PIB) in a polymeric matrix (PDMS) under a shear flow. The viscosity ratio was near unity, but the elasticity ratio of the droplet to the matrix was higher than 100; that is, the matrix phase was nearly Newtonian under the conditions of the experiments. In a weak shear and for small droplets [Ca < 5], the droplet stretching was found to be along the flow direction, whereas in a strong shear and for large droplets [Ca > 5], the stretching was along the vorticity axis with a broad distribution of aspect ratios. From the rheological properties, it was found that the time scale of the development of the normal force in the droplet phase was comparable to that of the development of vorticity alignment.

Mighri and Huneault (2001) studied the deformation and breakup of a single droplet of viscoelastic Boger fluid in a Newtonian matrix, sheared in a transparent Couette flow cell. At low shear rate, they found that the steady-state deformation increased with shear rate as expected, but above a critical shear rate [Ca ~ 5] the deformed drop began contracting in the flow direction and changed its orientation to the vorticity axis. With further increases in shear rate, this elongation in the vorticity direction increased until breakup finally occurred They proposed that the critical shear stress for elongation of the droplet in the vorticity direction is probably related to the values of the first and second normal stress differences and their dependencies on shear rate. They also suggested that this stretching occurs because of the flow-induced circulatory flow in the droplet that produces an elastic circular hoop stress in the plane of the shear and the shear gradient that squeezes fluid out along the axis perpendicular to this plane, that is, along the vorticity axis. They surmised that in a startup of a steady shearing flow, the deforming viscous forces rapidly reach a steady-state value, but the normal stresses generated by the dispersed phase requires a longer time, which causes a gradual increase in the elongation along vorticity axis until a steady-state deformation or breakup is attained. When a droplet was highly stretched in the vorticity direction, they observed small rocking instabilities in the velocity gradient direction causing the two ends of the droplet to sample significantly different velocities periodically, which ultimately tore apart the droplet into two or more smaller drops.

Lerdwijitjarud *et al.* (2002) studied the influence of elasticity on dispersed phase droplet size in immiscible blends in simple shearing flow. They utilized polystyrene and high density polyethylene as pairs of polymer blends at the fixed viscosity ratios of 0.5,1 and 2. Shearing flow were applied by using a cone and plate rheometer, and the steady state number and volume-mean averages of droplet diameters were observed by using an optical microscope. They found that the values of the steady state capillary number of all systems increased with the first normal stress difference ratios and followed a power law with scaling exponents between 1.7 and 1.9.

Recently, single viscoelastic droplets in Newtonian or viscoelastic matrices have been observed microscopically in simple shearing flows. Lerdwijitjarud *et al.* (2003) observed deformation and breakup of isolated droplets of weakly elastic fluid ($Wi_d \leq 0.02$) in a Newtonian matrix, and found that droplet elasticity produces a slight (up to around 20%) increase in Ca_c, the critical capillary number for droplet breakup. The breakup mechanism appeared to be similar to that in a Newtonian fluid; i.e., the droplet deformed increasingly in the flow direction as the shear rate was gradually increased, until breakup occurred. Elasticity of the droplet produced a reduction in the degree of deformation at any given shear rate and a greater critical deformation at breakup, resulting in a higher Ca_c. However, at the highest Weissenberg number, this effect appeared to be saturated, leading to only a modest increase in Ca_c.