CHAPTER II
LITERATURE REVIEW

2.1 Effect of Elasticity

Levitt and Macosko (1996) studied the influence of the normal stress difference on polymer drop deformation for blends of polypropylene drops of various viscosity and elasticity values. Drops were sheared in a polystyrene matrix by using two transparent counter-rotating parallel disks which provided a simple shear flow. They found that highly elastic drops forming the minor phase stretched perpendicular to the flow direction and the width of the flattened drops depended on the difference in elasticities between the matrix and the drop or the second normal stress differences of the two phases.

Mighri, Ajji and Carreau (1997) studied the effect of elasticity on drop deformation in elongational flow driven through a transparent channel of plexiglasses with a converging and diverging cross sectional channel. They proposed that the drop deformation decreased with increasing elasticity. On the other hand, the matrix elasticity had the opposite effect. 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 reported that for K' < 0.2, the matrix elasticity had a more drastic effect on the drop deformation than the drop elasticity. However, for K' > 0.2 the drop deformation was more affected by the drop elasticity.

Mighri, Carreau, and Ajji (1998) studied the influence of elastic properties on drop deformation and breakup in shear flow. The matrix phase was prepared from a 92 % maltose syrup with various amounts of distilled water (7.9-8.0%) and varying PAA (0.0-0.1%). The drop fluids were prepared from 93 % PB with various amounts of kerosene (6.2-8.4%) and PIB (0.0-1.2%). The experiments were conducted by using two transparent parallel disks mounted on a R-18 Weissenberg rheogoniometer . They found that the matrix elasticity helped to deform the drop whereas the drop elasticity resisted the drop deformation. Breakup increased with increasing drop/matrix elasticity ratio, K'. For the matrix of high elasticity (K' <

0.37), the deformation of elastic drops in an elastic matrix under shear was higher than that of Newtonian drops in a Newtonian matrix at the same viscosity ratio and interfacial tension. However, for $K^{'} > 0.37$ the elastic drops deformed less than a Newtonian drop in a Newtonian matrix. Moreover, they proposed that the critical shear rate and breakup time increased with increasing elasticity ratio; for $K^{'} < 4$ the critical capillary number increased rapidly with rising $K^{'}$; and for $K^{'} > 4$ it achieved a maximum of about 1.75.

Migler (1999) studied the droplet vorticity alignment in model polymer blends by using a matrix phase of polymethylsiloxane and a droplet phase of a polybuthylene under a steady state shear flow. The viscosity ratio was near unity but the elasticity ratio of the droplet to the matrix was greater than 100. They found that in the limit of weak shear and small droplet (Ca < 5), the droplet alignment was along the flow direction, whereas for strong shear and large droplets (Ca > 5), the alignment was along the vorticity direction when the distribution of aspect ratio was broad.

Tretheway and Gary Leal (2001) studied the deformation and the relaxation of Newtonian drops in planar extensional flows of a Boger fluid of a Newtonian drop suspended in PIB/PB Boger fluid. The suspending fluid was undergoing a planar extensional flow produced in a four-roll mill. They proposed that increasing elasticity of the suspending fluid had a pronounced effect on both the deformation and relaxation of a drop. For steady flows, as the strength of viscoelastic effects in the suspending fluid was increased, the drop became more deformed, with ends that were generally more pointed. This led to a decrease in the maximum critical capillary number for the existence of a steady deformed drop shape. In transient startup and step flows, the elasticity of the suspending fluid produced a large deformation shape that was more pointed at its ends. However, at smaller deformation, the elasticity of the suspending fluid retarded the relaxation of the drop.

Mighri and Huneault (2001) studied the deformation and breakup mechanisms of viscoelastic drops (Boger fluid) in a Newtonian matrix (PDMS) in a shearing flow in a transparent Couette flow cell. At low shear rate, the authors found that the dispersed drop was oriented along the flow field and drop deformation increased with shear rate, as expected. However, when a critical shear rate was reached [Ca ≈ 5.5], the deformed drop began to contract in the flow direction. When increasing the shear rate over this critical value drop contraction occurred and was followed by elongation perpendicular to the flow direction. This elongation increased with shear rate until the final breakup occurred. They observed small rocking instabilities in the velocity gradient direction resulting in a large velocity difference between one end of the droplet and the other. When this rocking motion set in, quick elongation of the drop tore it apart in two or more smaller drops. They suggested that this stretching occurred because the drop fluid was then squeezed and forced to flow along the neutral direction, similarly to the rod climbing effect. With increasing shear rate, higher normal stresses were developed in the drop fluid along streamlines, inducing more squeezed forces, and consequently larger vertical deformation.

Lerdwijitjarud et al. (2002) studied the influence of elasticity on dispersed-phase droplet size in immiscible polymer blends in simple shearing flow for blends of polystyrene drop and the high density polyethylene matrix at fixed viscosity ratios of 0.5, 1, and 2 by using a cone and plate rheometer. They proposed that after steady-state shearing, the viscoelastic drops were larger than the Newtonian drops at the same shearing stress and the value of steady-state capillary number increased with the first normal stress difference ratio and followed a power law with scaling exponents between 1.7 and 1.9.

Lerdwijitjarud et al. (2003) studied the influence of weak elasticity of dispersed phase on droplet behavior in simple shearing flow for blends of polybutadiene in poly(dimethylsiloxane). Both isolated droplets and 20% dispersed phase blend were investigated under conditions of equal viscosities of droplet and matrix fluids. They found that the droplet-phase elasticity increasesd, the steady-state shape deformation at fixed capillary number, Ca, decreased and the critical capillary number for droplet breakup increased. For a 20% dispersed phase blend, the steady-state capillary number calculated from the volume-averaged droplet diameter increased with increasing droplet-phase elasticity, but was smaller than for isolated droplet. They suggested that increasing shear rate present concentrated blends were more important than coalescence in influencing steady-state droplet size.

Cherdhirankorn et al. (2003) studied dynamics of vorticity stretching and breakup of isolated viscoelastic droplets in an immiscible viscoelastic matrix for blend of elastic polystyrene droplets dispersed in an elastic high density polyethylene matrix in a simple shearing flow between two transparent parallel disks. They selected two blend systems with viscosity ratio near unity, but of different elasticities for the droplet and the matrix phases. They found that, in system A with higher elasticity, the droplets initially deformed in the flow direction after startup of steady shear but then began reverting to a spherical shape, and eventually deformed in the vorticity direction. In system B with lower elasticity, the droplet first deformed in the shear direction, and thereafter continuously contracted in the flow direction until it reached its steady-state shape. Moreover, the droplet deformed increasingly along the vorticity with increasing capillary number, and above a critical capillary number Ca_c, breakup occurred.

2.2 **Effect of Viscosity Ratio**

Tavgac (1972) studied the deformation and breakup of viscoelastic drops suspended in a viscoelastic fluid under shear flow. He observed that, depending on drop/matrix combined properties, the elastic forces arising from the droplet phase may have a stabilizing or destabilizing effect on the breakup process. At high values of viscosity ratio, an elastic droplet unfavored the breakup, but destabilizeed the drops at low values of viscosity ratio and he also reported that the breakup of viscoelastic drops in viscoelastic matrices occurred at lower shear rates under transient conditions compared to steady-state conditions.

Hobbic and Migler (1999) studied the dispersion in polystyrene polyethylene (PS/PE) systems over a wide range of viscosity ratio up to 240. The authors observed a variety of droplet shapes as a function of shear rate and viscosity ratio. For high PS/PE viscosity ratio, k = 240, they obtained critical capillary numbers for droplet vorticity alignment of around 53, 13, and 11 for the viscosity ratios, η_r, of 1.8, 22, and 240, respectively.

2.3 **Effect of Capillary Number**

Vassilios et al. (1998) studied the deformation and breakup machanisms of single drops during shear of isotropic hydroxypropylcellulose immersed in a polydimethylsiloxane matrix by using a rheo-optical technique. The nonstationary deformation and breakup mechanisms of drops were characterized at large capillary number. The deformation of threads follows a pseudo affine deformation for Ca/Ca_{crit} larger than 2.5 and above a certain strain. They reported that the thread rupture results from a competition between end pinching and capillary instability mechanisms. The end pinching mechanism occurs at a specific scaled strain, which included the initial drop size and the applied shear rate. Capillary instabilities develop when the thread diameter reaches a critical value inversely proportional to the applied shear rate. The time necessary for the total rupture of a thread depends on the initial drop diameter, the applied shear rate, and the critical thread diameter or the applied shear rate can result in differents influences on the time necessary for breakup.

Jong-Wook and Gary Leal (2001) studied drop deformation and breakup in an extensional flow at high capillary number for blends of Newtonian drops in a suspending fluid, and studied Newtonian drops in a viscoelastic suspending fluid. They found that the critical degree of stretch for breakup increases sharply with increase in the capillary number that characterizes the stretching process for Newtonian drops in a Newtonian suspending fluids. Newtonian drops in the viscoelastic boger fluid were found to be slightly more stable than the same drops in a Newtonian fluid when stretched at strain rates just exceeding the critical value. The critical elongation ratio necessary for the drops to break, upon cessation of flow, is increased by about 20 %, approximately 2.15 times the critical value. Large drops in the viscoelastic fluid are destabilized in a Newtonian suspending fluid, while smaller drops are strongly stabilized.