CHAPTER I
INTRODUCTION

Rheology is concerned with the relationship between stress (force/unit area), strain (change of shape) and time. The flow of polymer melts in actual processes is very complex, involving three dimensional flow under non-isothermal and non-steady state conditions. In many cases it is reasonable to approximate behavior by modeling the flow as a series of simplified idealized viscometric flows. The objectives of rheology are to understand the behavior of the polymer melts relevant to the conversional process and to predict the performance of the polymer in actual industrial uses.

Nowadays, inorganic fillers play an important role in plastics industry. The purposes of their use do not only confine to the cost reduction, but to improve mechanical performance like rigidity, dimensional stability, toughness, and transparency as well (Thio *et al.*, 2002, Da Silva *et al.*, 2002). The level of such improvements depends significantly upon type, size and shape, content, and surface treatment of the fillers (Tabtiang and Venables, 2000, Chan *et al.*, 2002, Gonzalez *et al.*, 2002). The latter determines the interaction between the polymer matrix and the fillers at the interface.

Not only the presence but also the distribution of the fillers affects a great deal the viscoelasticity of the polymer matrix. The distribution of the filler within the polymer matrix can be improved by surface treatment with a dispersant, e.g. stearic acid, which helps reduce the viscosity of the matrix and, to some extent, prevent the fillers from forming a network (Thio *et al.*, 2002, Nowaczyk *et al.*, 2004, Haworth *et al.*, 2000). An understanding of the rheological characteristics of filled polymer systems is beneficial to the design of polymer processing equipment, with the ability for predicting the energy requirement, optimizing the processing conditions, and correlating with the structural development (Hornsby, 1999).

In polymer processing, the properties of the end products are dependent on not only the materials used, but also the design of the processing equipment, such as the geometry of the screw and die (Sombatsompop and Dangtungee, 2001, 2002). Die or extrudate swell is an important phenomenon determining the size and quality of the extrudate products. Importantly, the extrudate swell can be used to assess the elasticity of the polymer upon melt extrusion. The mechanism and degree of swelling of the extrudate are usually explained in terms of elastic recovery or effect of residence time on the applied stresses (Sombatsompop and Dangtungee, 2002, Nair *et al.,* 2002, Liang, 2002). During a converging flow through a die, polymer molecules tend to uncoil. The entanglements will, to some extent, prevent the molecules from slipping past one another, thus preventing total relaxation of the molecules. At the die exit, recoiling of the molecules occurs to some extent, causing the extrudate to swell (Hornsby, 1999).

Extrudate swell and melt fracture are important phenomena addressing the quality of polymeric products. Studies of these phenomena on unfilled polymeric melts have been well-studied and well-documented. Most of the time however, polymeric articles are made with addition of various fillers and additives to improve the properties of the resulting polymeric product. Extensive studied have been reported by taking swelling ratio as a function of length and diameter ratio (L/D), shear stress, shear rate, exit pressure loss, die angle, and so on (Sombatsompop and Dangtungee, 2001, Liang, 2004, Fujiyama and Kawasaki, 1991, Huang, 2003).

In various polymer processes, the rheological properties were important factor to be investigated, which control the quality of products (Gupta, 2000, Dangtungee *et al.*2005). Since both shear and elongational deformations occurred concurrently during actual processing, complete understanding on the effect of both types of deformation is necessary. An investigation of rheology under shear and elongational deformations can be carried out with a lot of instrument, e.g. cone and plate or parallel disk rheometer (for shear deformation) and tensile creep or filament stretching (for elongational deformation) (Gupta, 2000). The most common technique used to study rheological properties of polymer melts is capillary rheometry (Sombatsompop and Dangtungee, 2001, Bryson, 1970). In fact, both type of deformations during flow through a capillary die. Without the end effect, the shear rheological properties can be investigated (http://www.me.mtu.edu/~mahesh/papers, Fujiyama and Inata, 2002), while the elongational rheological properties can be studied theoretically when the convergence flow (i.e. the end effect) is taken into account (Huang, 2003, Cogswell, 1994). As a result, both shear and elongational rheological properties can be conveniently studied using capillary rheometry.

In this research, it is our objective to fully investigate the rheological properties of polymer melts filled with various fillers. Various rheological phenomena (e.g. shear and elongational rheological behavior, extrudate swell, and melt fracture) are to be fully investigated. The effects of type, size and shape, surface treatment, and content of the fillers on the rheological behavior are to be examined.