CHAPTER I

INTRODUCTION

The examination of fracture surface, fractography has been used widely in the study of metal, glass and polymer materials. It is generally used to characterize the surfaces where fracture has originated, in which direction the crack has traveled and the general nature of fracture such as ductile or brittle fracture. More detailed study may also provide information about velocity of fracture and the incidence of subsidiary or secondary fracture. (Andrew, 1968 and So, 1988).

The most obvious, polymer materials are inhomogeneity. Any point of weakness in the material will tend to attract the fracture through itself. Fracture can be a tool for the study of microstructure and has indeed been used to reveal such structure as phase separation and polymer crystalline morphology (Andrew, 1968).

1.1 General Morphology of the Fracture Surface

The fracture origin is the point at which a crack is first nucleated. It usually coincides with the location of the minimum materials resistance to fracture. Local stress variation can result from a variety of factors. The presence of inhomogeneities such as voids, sharp corners or sudden changes in wall thickness all contribute to stress concentration (So, 1988).

The fracture surfaces of broken specimen of semicrystalline, amorphous, thermoplastic polymer as observed through optical or electron microscopy can be divided into many regions such as mirror region, hackle region, Wallner lines, discontinuous growth bands, and parabolic marking. These regions are detailed in the following sections (Collyer, 1994, Andrew, 1968, Wolock, 1964).

1.1.1 Mirror Region

Mirror regions are close to the defect where the fracture starts. The initial stage of crack growth results from the rupture of a fibril at the trailing edge of a craze. Crazes are very thin, planar defects, therefore, they form a very flat and smooth fracture origin, commonly known as the mirror region.

In fracture surfaces of PVC and PC materials, mirror region is commonly observed as the second region in which the origin of unstable fracture is identified at the end of the stable crack growth region. The unstable fracture origin is usually located on the interior of the specimen near the fracture (Lee et al., 1987).

1.1.2 Hackle Region

Hackle lines are easily recognized by the outward divergent lines pointing along the crack propagation direction. Hackle regions tend to appear in areas where the stress field is changing rapidly either in direction or magnitude. Since hackle regions are a prominent feature on the surface, the crack propagation direction can be easily identified. The divergent nature of the hackle lines is advantageous in locating the crack origin.

1.1.3 Wallner Lines

Wallner lines are observed mainly in the mirror area. They are most prominent on the fracture surface of glass, but have also been detected in a less prominent fashion in polymers. The Wallner lines are formed when a reflected stress wave intersects a propagating crack; they are not true crack front marking. In practice, stress wave velocities are so much higher than the crack velocity that Wallner lines may be considered as a snapshot of the crack front during its propagation. The shape of the resulting curve depends on the crack velocity and stress wave velocity ratio.

Typically, Wallner lines are curved marking similar to crack front marking, with the fracture initiation site located on their concave side. As such, they may be useful in locating the fracture origin.

1.1.4 Discontinuous Growth Bands

The model for discontinuous growth bands formation occurs by fibril strengthening which contributes to orientation hardening. At some point, it is expected that the most highly stresses fibrils will disentangle and fracture. With the breakage of each additional fibril, the remaining unbroken ligaments assume an ever-increasing load and associated strain. These fibrils then become stronger as a result of further orientation hardening. So the sudden breakdown of the band is believed to correspond to a cyclic strain-induced stretching of the craze fibrils. Moreover the fracture origin will be located by tracing back along the crack direction on the concave side of the curve markings (Mark et al.,1985).

Although Wallner lines resemble discontinuous growth bands, there are at least two identifying characteristics that separate the two fracture features (Phillips and Kerlins, 1976).

- Wallner lines are usually found only in very brittle materials or phases, where discontinuous growth bands are seldom observed.

- Discontinuous growth bands may propagate in different directions, but they never cross each other as Wallner lines do.

1.1.5 Parabolic Marking

This geometric marking is produced by the intersection of the main crack front with secondary crack propagation which were activated by the advance stress wave. If the velocities of two cracks are equal, a parabola is formed. The parabolic markings were produced divergently in the propagation direction of the main crack. Thus the nose of the parabola always points to the crack source (Mill, 1993).

1.2 Background and Literature Review

Zimmerman and Jones (1994) have studied the fractography of polyetherimide (PEI) by using SEM to characterize and compare mode of fracture, which consisted of tension, bending, impact, biaxial flexure, torsion, fatigue and cutting. The stressed PEI samples exhibited ductile deformation and finally brittle fracture shown by primary fracture surfaces : mirror, transition region with hackle lines, and a rough region with Wallner lines. The impacted samples exhibited stress cracking from the point of impact.

The influence of processing history on the fatigue of nylon 6,6 was studied by Wyzgoski and Novak (1992). They examined microtomed sections by optical microscopy and found that a reduction in spherulite size occurred with reprocessing. Furthermore they used SEM to study the fatigue fracture surface. Patchy type regions were observed on the fracture surfaces. After reprocessing of nylon 6,6 materials, there are no dramatic changes in size of the patchy area. These patchy area often appears to initiate from impurity particles. They concluded that the basic mechanism for fatigue crack advance by the nucleation and aggregation of crazes (patchy region) is not changed by reprocessing. Moreover no change in degree of crystallinity was detected by thermal analysis.

Khanna et al. (1988) reported that the processing history of nylon 6 has a memory effect which in turn affects its crystallization rate from the molten state. The mechanical properties and morphology of a nylon 6 article depend upon the processing technique, compression or injection molding, as well as the processing history of the nylon 6 resin itself.

Wolock (1964) studied fracture of PMMA and reported that the initial stages of fracturing are usually accompanied by local plastic deformation. The fracture progresses slowly form its origin until reaches a size which is critical for applied stress, at which point it becomes unstable and propagates rapidly. The region of slow growth contains the origin of failure in a tension specimen; this smooth area is known as the mirror region. Beyond the mirror region, there is a transition region which is usually an area of increasing roughness in a tension specimen. The next area contains a number of geometric figures, resembling parabolas and hyperbolas. The stress level and the crack velocity increase still further and a shattering type of failure is observed.

Lee et al. (1987) studied the plane strain fracture toughness of several tough engineering plastics. The change in the surface morphology of PVC corresponds to the abrupt transition of the crack speed at instability. Three characteristic regions have been identified for PVC. In the multiple craze zone, the surface topology consists of many kinds of crazes, which finally coalesce and interconnect. The second region is a more smooth, mirror region, appearing relatively smooth with little craze material appearance. Beyond the mirror zone is a third region where the crack accelerate and spread radically forward, eventually covering the full specimen thickness.

1.3 Objectives

As discussed in the previous sections, mechanical deformation can bring about the permanent morphological change in polymer. The extent of these changes was seen to depend on physical and chemical constitution. The fracture surface also depends on physical and chemical parameters characteristic of the particular polymer. For these reasons this present work aims to achieve the following.

1. To illustrate the fracture surface under impact loading and tensile stress.

2. To investigate the effects of reprocessing on morphological structure of engineering plastics compared with commodity plastics.