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The effect of natural weathering on the mechanical, morphological and thermal properties of high impact polystyrene (HIPS)

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Abstract

The effect of natural weathering on the mechanical, morphological and thermal properties on the high impact polystyrene (HIPS) and cold drawn HIPS are investigated. After natural weathering period of 8760 h, under known meteorological parameters, the changes in mechanical properties are investigated by using tensile, instrumented impact and hardness tests. Thermo-mechanical properties are characterized by using thermomechanical analysis (TMA) and melt flow index (MFI). Fractured surfaces of the materials are investigated by scanning electron microscope (SEM). Natural weathering effects on fracture mechanisms are discussed by means of fractographical analysis. Remarkable morphological changes were observed especially at the surface of the material. This results in dramatic loss in mechanical properties.

Keywords: High impact polystyrene; Cold drawing; Natural weathering; Fractography

1. Introduction

High impact polystyrene is a classic example of a blend in which the incorporation of an elastomer phase in a brittle matrix promotes an acceptable level of toughness [1]. Since the 1960s, the development, use and understanding of rubber-toughening have been subject of a massive amount of industrial and academic research [2–4].

A number of factors can contribute to the failure of toughened polymer when impact occurs. Failure mechanism (crazing and shear yielding), temperature and notch may affect the toughening process [5]. Crazing happens before fracture, but not to a great extent. However, when rubber is added to PS to form high impact polystyrene (HIPS) a great amount of crazes are promoted which make fracture occur only at high strains [6].

It is well known that the physical properties of polymeric materials are much influenced by molecular orientation. Cold drawing occurs because at low extension rates the molecular chains in the plastic have time to align themselves under the influence of the applied stress. Thus the material is able to flow at the same rates as it is being strained [7,8]. Accompanying the molecular processes occurring during the orientation are macroscopic changes in the shape of the tensile specimen [9].

The durability of organic materials, exposed to the outdoor environment, is determined to a large extent by the solar radiation on this material [10,11]. Natural weathering gives the most practical and the faithful data regarding the variation of the performance of the products in use [12]. Natural weathering of polymer refers to the exposure of polymers to natural outdoor conditions where direct or indirect sunlight, heat, oxygen, moisture and other factors contribute to the degradation of materials properties. Micro organisms, ozone, airborne chemical pollutants such as sulphur oxides and nitrogen oxides and salt are some of the factors that are of significance [13]. Exposure to the outdoor

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environment not only affects the polymeric material itself, but also acts upon other components within the matrix, such as dyes, pigments, processing additives, absorbers and stabilizers. Each of these components reacts to the environment individually or in combination with other components [13–16]. Polymer degradation involves the change of one or more physical properties, resulting in loss of the suitability of the material for the material for the intended application.

The most common specifications relate to the mechanical properties, including strength, stiffness, hardness, and elasticity as well as dimensional stability. Other important properties include optical characteristics, such as colour, gloss, and light transmission, and electrical properties [13].

The thermal analysis is frequently used to describe analytical techniques which investigate the behaviour of a sample as a function of temperature. Using TMA techniques, the dimensional changes caused by external force are directly measured as a function of temperature [17].

Qayyum and White [18], Bedia et al. [12], Sing et al. [19], Baum et al. [20], Van Krevelen and Hoftyzer [21], Ragab et al. [22], Uzomah and Onuoha [23], Schoolenberg [24], Sharbel et al. [25], Kalfoglou [26], Sınmazçelik [27] investigated the effects of natural weathering on the polymers. The objective of this study is investigating the effect of natural weathering and cold drawing on HIPS.

2. Experimental

2.1. Material

High impact polystyrene (HIPS) material was kindly supplied from PETKİM (the Turkish petrochemical company). The traditional name of the styrene-butadiene blend was A-825E. The tensile and charpy impact testing samples were produced by injection moulding according to manufacturer's suggestions.

2.2. Natural Weathering Procedure

The natural weathering experiment was performed in İzmit /Turkey. Half of the samples were placed on the roof of our research building and was exposed to natural weathering for 8760 h (365 days). The geographic coordinate of the weathering test apparatus was 40° 45′ 05 N/29° 54′ 94 E. The research building was located nearby İzmit Bay of Marmara Sea at a distance of 250 m and attitude of 3 m from the sea level. Natural weathering experiments were performed according to ASTM D 4364 and ASTM D 1435. The original (untreated) samples (other half of the samples) were kept in controlled laboratory atmosphere after they manufactured.

2.3. Tensile tests

The tensile tests were carried out in Instron 4411 with existing capacity of 5 kN according to ASTM D 638 standards. Tensile speed was 50 (mm/dk). Cold drawing process was performed under the crosshead speed of 1 mm/min at the room temperature. The samples were stretched up to 25 mm ± 0.1, which corresponds to 16% plastic deformation (Fig. 1). Making easy to follow the cold drawn HIPS is symbolized as cHIPS.

2.4. Charpy impact tests

A standardized Instrumented Ceast pendulum impact testing machine (Resil 25) was used at 23 °C and 50% relative humidity in order to investigate fracture behaviour of the samples. Hammer length and mass were

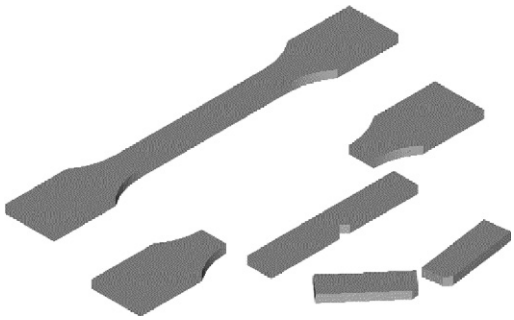

Fig. 1. Cold drawn impact samples manufacturing procedure.

0.327 m and 1.254 kg, respectively. The sampling time was 8 μs. In this way, it was possible to analyse the formation of crazes and associated particle damage at a velocity of the striking nose at the moment of impact of approximately 0.93 m/s and maximum available energy was 0.54 J. A razor blade was introduced into the notch and lightly tapped on it. The sample dimensions were 63 × 12.8 × 6 mm. Before discussing the results it is important to understand the approach used in the analysis of force-time curves, which is critical in determining the impact characteristics of materials. Upon impact of the pendulum, the force rises sharply to a maximum value (F_{max}) and then gradually decays to zero due to catastrophic failure. Total area under the force-time curve gives the impact energy for the system (E_{max}). These curves can be divided in two regions. The first region is the crack initiation and the second is the crack propagation regions. The areas under each region give the energy for these processes, which are defined as energy for crack initiation (E_i) and energy for crack propagation (E_p). The spikes in the first region are due to inertial oscillations of the sample.

Impact testing has allowed the toughness of PS to be correlated with the morphology of the dispersed rubber phase. Different deformation mechanisms were effective, depending on the location of the observed stress-whitened zone relative to the notch tip. The apparent fracture mechanisms in rubber-toughened PS and cold drawing HIPS were also studied by scanning electron microscopy.

2.5. Scanning electron microscopy studies

The surfaces of the fractured samples were examined by scanning electron microscopy (SEM). Fig. 2 is illustrated the locations of the cross section of the samples as I, II and III. The location I was located in the mid plate nearby the notch. The location II was located at the side wall of the sample, which is highly plastically deformed and exposed to naturally weathering. The location III was located in the middle of the sample far from the surface.

2.6. Thermomechanical analysis

Thermomechanical analyzer (TMA) measures the dimensional changes of a material as a function of temperature and time. It is possible to determine the glass transition temperatures and thermal expansion coefficients. Thermomechanical analyses were performed by Shimadzu TMA analyzer

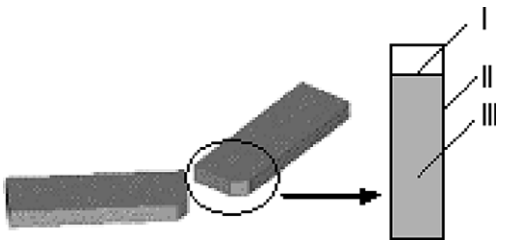

Fig. 2. Charpy impact test samples and the locations on the cross section of the sample.