THE FAILURE BEHAVIOUR OF UV DEGRADED PLASTIC PRODUCTS

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Chemical and physical changes occur in the surface layer of a plastic product, due to ultra-violet radiation in presence of oxygen. These changes lead to brittle behaviour and loss of mechanical properties. However the decrease in mechanical properties is not monotonous because of the complex interactions between the physical properties of the material and the chemical and physical reactions. A description of the relation between the degree of degradation and the mechanical properties is given.

OBJECTIVES

The research concentrates on three questions which arise in industrial practice, concerning the reliability of plastic products used under various climatic conditions.

1. DESIGN: How can one extend the lifetime of plastic products used outdoor in terms of material (& additives), production (-method) and product geometry?

2. QUALITY: How long will a product meet the service requirements under various climatic conditions?

3. MAINTENANCE: How can one determine the remaining lifetime of the product in use, in a non-destructive way?

These questions are not only of interest because of economics and safety, Vink (1), but also because of environmental reasons.

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The answers to these questions require determination of:

a. The parameters which are responsible for product failure in terms of not meeting the requirements (which parameter(s) influences the mechanical behaviour?).
b. The dependence of the parameters on the climatic conditions.
c. The interaction between the parameters.

In our research we concentrate on measurement of changes in impact behaviour of polyolefins, due to U.V. radiation in course of time.

Changes in parameters which are commonly used to describe the decrease of mechanical properties are the formation of carbonyl groups, rate of oxygen uptake (1), shift in molecular weight, shift in surface hardness, decrease of tensile properties of films taken from the surface layer Schoolenberg (2), change in density, appearance of fracture surface, colour change and presence of spontaneous cracks.

The depth of embrittlement is thought to be of prime importance in predicting the failure behaviour and can be compared to a notch with equivalent depth in some cases (1).

The degree and depth of degradation is influenced by factors like degree of cristallinity, orientation, residual stresses, external stresses, temperature, intensity of U.V. radiation, etc. A number of variables are systematically varied to determine their influence.

Results of experiments on a commercial non stabilised PP copolymer (DSM Stamylan 56M10, 8% PE-EPR) are given below.

RESULTS

In figure 1 a plot of the maximum bending stress versus degradation time is given. It shows the results of samples tested in three point bending with a strain rate of 60 1/s at the outer fiber.

The degraded layer induces brittle crack growth. When the crack is arrested at the interface between degraded and non degraded material, the crack growth will be ductile when the crack is initiated again. This cause a clear distinction which can be easily measured with the study of the fracture surface by means of an optical microscope and is called 'effective degradation depth'.

In figure 2 the maximum bending stress versus the effective degradation depth for degraded samples and versus notch depth for notched samples is given.

Apparently the failure behaviour of the copolymer is controlled by net section yield. Some samples however fail at a lower stress level (fig. 1). This is thought to be due to the crack speed effect, mentioned before by Rolland et al (4) and (2) for PP. In these cases no clear distinction between brittle and ductile crack growth could be detected. The crack speed effect was not found in experiments with commercially stabilised and pigmented HDPE samples.

The occurrence of the crack speed effect is supposed to be controlled by the stresses in the surface layer and the thickness of the embrittled layer. The crack speed effect was not found when cracks started spontaneously or were introduced deliberately. Because of the existence of the crack speed effect, it is not enough to simply exchange data of the U.V. sensitivity of a material.

Because the degradation processes take place very localised and the impact behaviour is very sensitive for local defects, the results of for example carbonyl index measurements, which gives average values, have no good correlation with the impact behaviour. The depth of embrittlement measured by means of the microfoil tensile test seems to be a very sensitive method with good correlation with the mechanical properties (5).

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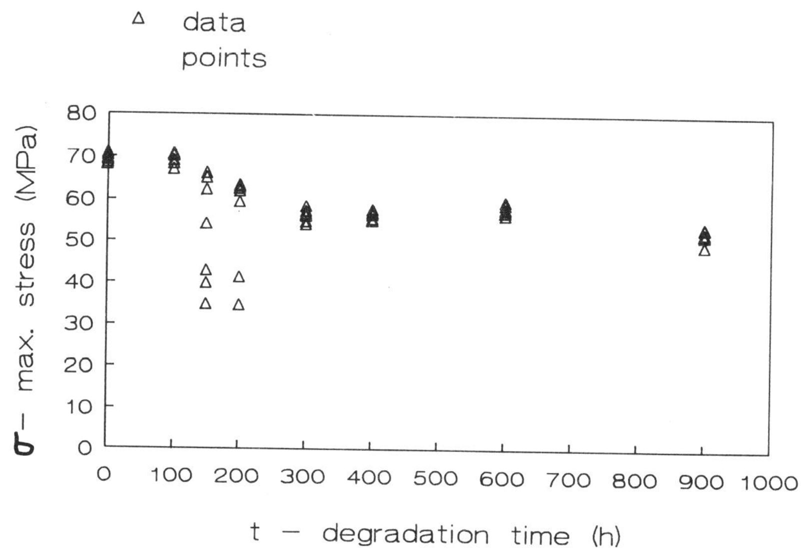

Figure 1. Maximum bending stress plotted against degradation time

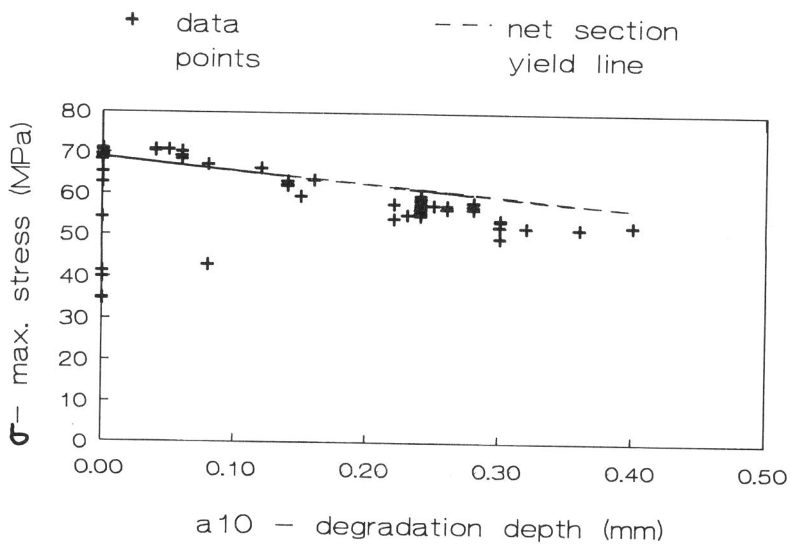

Figure 2. Maximum bending stress plotted against effective degradation depth