ENVIRONMENTAL STRESS CRACKING RESISTANCE OF HIPS UNDER CYCLIC LOADING USING CRACKED ROUND BAR SPECIMENS

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Abstract

The service life of polymers depends strongly on their loading conditions and the environment surrounding them. Prolonged contact of a polymer with an oily or fatty environment increases the tendency of crazing and thus shorten the service life. The objective of this paper was to investigate two different high-impact polystyrene polymers (HIPS) in terms of their environmental stress cracking resistance (ESCR) in air and sunflower oil environments by cyclic testing. It was shown that the HIPS grade with bigger rubber particles, even though it has lower short-term mechanical performance in tensile modulus, yield strength, and notched impact strength, is preferrable in terms of ESCR and should be used in fatty environment applications.

1. Introduction

Environmental Stress Cracking (ESC) is one of the most common causes of unexpected brittle failure of currently known thermoplastic polymers. Amorphous polymers in particular tend to ESC due to their loose structure, which makes it easier for the liquid to penetrate the polymer. Especially in application areas such as food packaging, polymers come into contact with a wide range of different medias like for example with oils or fats. Prolonged contact of a polymer with an oily or fatty environment increases the tendency of crazing which directly affects the deterioration process. This paper describes the investigation of two different high-impact polystyrene polymers and their environmental stress cracking resistance in air and oil environments. Moreover, this paper includes investigations concerning the immersion time in oil prior to testing to get a saturated testing material for a neglection of the testing time influence itself, the test frequency, and the influence of blade-geometry for notching. This work was part of a round robin test with the Technical Committee 4 (TC4) of the European Structural Integrity Society (ESIS).

2. Results

The effects of the air and oil environment in terms of their ESCR were investigated with cyclic loadings using cracked round bar specimens (CRB). Needed immersion time in oil prior to testing was found to be 48 hours for a saturation of the specimens which was required to neglect the effect of the testing time itself. For conduction of the cyclic tests a pure tension load ratio (R) of 0.1 was chosen. Tests were also performed under constant initial stress intensity factor ranges ($\Delta K_{I,ini}$) conditions to explore the effects of cyclic frequencies between 1 and 20 Hz on the fatigue crack growth behavior in air environment. There appears to be no systematic effect of frequency, apart from a possible time dependence and hence a dependence on creep deformation, so that tests at 10 Hz appear to provide representative conditions for assessing crack growth behavior of the materials without a hysteretic heating. To determine the blade-geometry dependency for notching, seven different blades were tested with consideration of the handling behavior while processing, the availability, optical notch visibility, and of test results at same loadings deriving different cycles to failure. These investigations resulted in a preference for the razor blade with a thickness of 0.1 mm. For the cyclic measured ESCR maximum loading forces from 150 N to 600 N, therefore $\Delta K_{I.0}$ from 0.07 MPa·m$^{0.5}$ to 0.35 MPa·m$^{0.5}$ were applied in the conduction of the cyclic tests. The results of the testing are shown in Fig. 1. The cycles to failure varied from $2 \cdot 10^4$ to $6 \cdot 10^6$, resulting in testing times ranging from 30 minutes to up to 7 days. Both materials (HIPS-A and HIPS-B) showed the same general trend of poorer performance in oil compared to an air environment. Reviewing the results of the two materials in the two different environments revealed a clear performance advantage. HIPS-A with larger rubber particles outperformed HIPS-B in every respect in the cyclic ESCR measurements. HIPS-B endures at the same stress levels nearly 10 times less cycles until failure than HIPS-A in air. This difference was even greater when tested in oil, due to the fact that HIPS-B is more prone to the media influence.

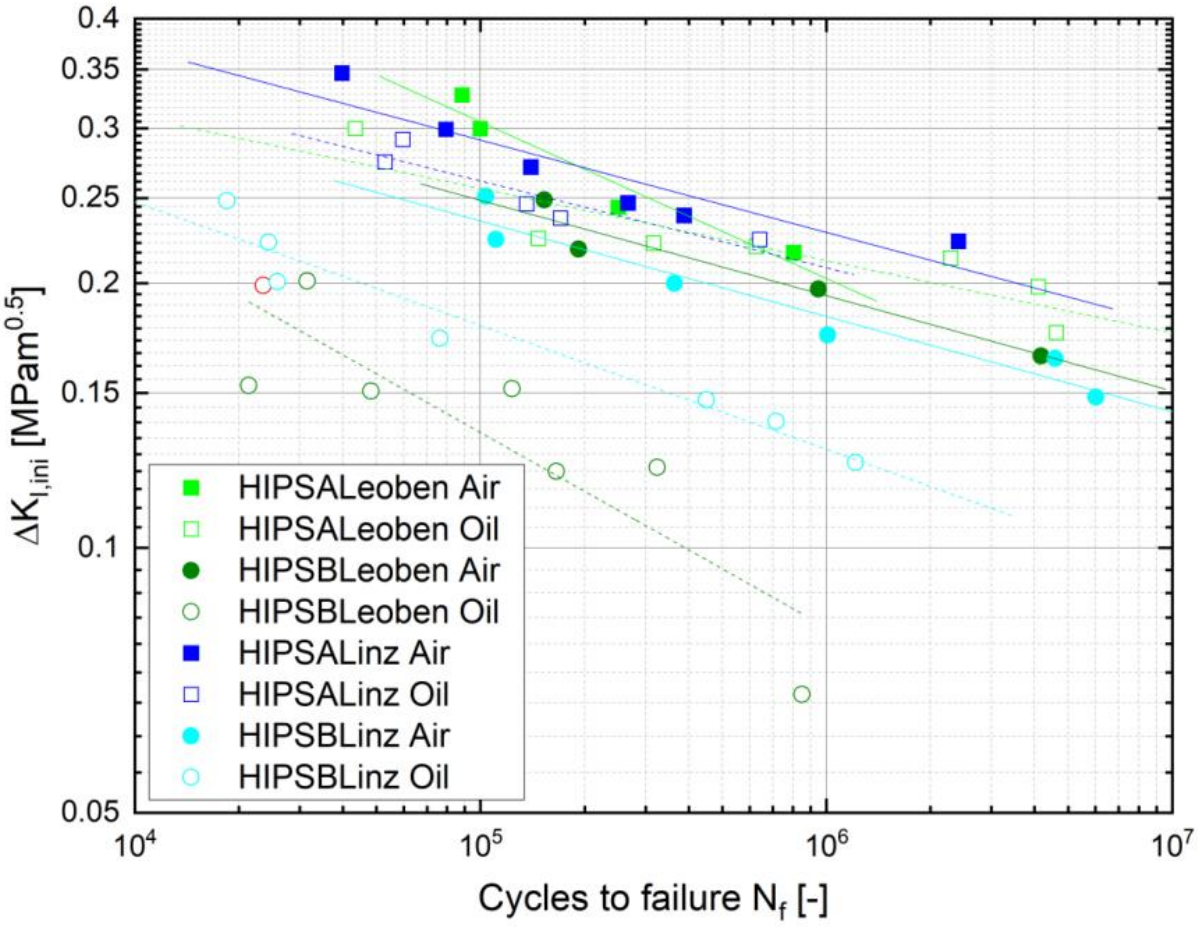

Fig.1 – Comparison of the ESCR of HIPS-A and HIPS-B at roomtemperature in air and oil environment in the cyclic testing with a test frequency of 10 Hz, a load ratio R = 0.1.

3. Conclusions

A clear tendency towards a weakened material due to the active medium was shown. The cyclic tests at lower stresses indicated a superior ESCR behavior for the special designed ESCR HIPS-A grade that contained larger rubber particles. Moreover, results showed an necessary oil immersion time prior to testing of 48 hours, an applicable test frequency of 10 Hz, and an preferred razor blade notching for the CRB specimens.

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