Brittle Fracture in Key-hole Notched Polymer Specimens under Combined Compressive-shear Loading

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ABSTRACT: In the present study, brittle fracture of the general-purpose Polystyrene (GPPS) is studied experimentally and theoretically under compressive-shear loading by using the Brazilian disk specimens containing a key-hole notch. The notched specimens are specified by different geometric parameters, i.e. the notch length and the tip radius. In this investigation, 84 fracture tests reported recently by the present authors are evaluated to assess the brittle fracture of key-hole notched specimens under compressive-shear loading. Two energy-based fracture models namely, the averaged strain energy density (ASED) and averaged strain energy density based on the equivalent factor concept (ASED-EFC) are proposed to predict the fracture loads of the tested GPPS specimens. The experimental and theoretical results are plotted for each case in the form of the fracture load versus the notch tip radius. Moreover, the analyses based on the finite element method as well as the experimental observations showed that although brittle failure in the test samples under compressive-shear loading takes place from the applied load side of the notch border by local tensile stresses, the notch bisector line and the other side of the notch border sustain compressive stresses. In fact this phenomenon states the concept of compressive-shear loading. Finally, it is shown that a good agreement exists between the experimental fracture load results and the theoretical predictions evaluated by using the two strain energy-based criteria.

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1- Introduction
Some notch features are not original, meaning that they are resulted from applying a repairing method to remove crack and damage emanating from the notch tip or border. For instance, if a small crack initiates from the tip of a U-notch, a usual repairing method is to remove the crack by drilling a hole having the radius equal to the crack length. After the repairing process, a new notch called the key-hole notch is created. Recently, a large number of experimental results dealing with brittle fracture of key-hole notched specimens have been published in the literature (see [1-3]). The purpose of the present research is to study the brittle fracture of the key-hole notched specimens reported in reference [4] under compressive-shear loading by using the two energy-based fracture criteria.

2- Fracture Test Results Reported in Literature
Present authors have recently published a research paper [4] in which a series of experiments on the key-hole notched Brazilian disk (Key-BD) specimen have been performed to assess experimentally the brittle fracture in key-hole notches under compressive-shear loading. The material utilized in the experiments has been a type of brittle polymer called the General-Purpose Polystyrene (GPPS). Fig. 1 shows the Key-BD specimen during mixed mode I/II fracture test. Three different values of loading angle (i.e. 30°, 50° and 70°) have been investigated. Also, the finite element (FE) analyses as well as the experimental observations of the Key-BD specimen have shown that although the right half of the notch border always experiences tensile stresses during the tests, the notch bisector line and also the other half of the notch border sustain compressive stresses, meaning that the entire samples are broken under mixed mode I/II loading with negative mode I conditions (see Fig. 2). In fact, this phenomenon states the concept of compressive-shear loading.

3- Energy-based Fracture Criteria
Two energy-based mixed mode brittle fracture criteria, namely the Averaged Strain Energy Density (ASED) and Averaged Strain Energy Density based on the Equivalent Factor Concept (ASED-EFC) are proposed to predict the experimental fracture loads. All numerical calculations are
The trend of the experimental results as well as the theoretical predictions which obtained from the two energy-based criteria show that the fracture load first decreases and then increases as $\beta$ enhances from $30^\circ$ to $70^\circ$ (see for instance Fig. 3). As seen in Table 1, similar trend is observed for the other tested GPPS specimens with different notch geometries and loading angles. Applying a constant load to the FE model and performing the energy-based FE analysis for each specimen...
under various loading conditions shows that the value of the ASED over a specified control volume first increases and then decreases meaning that the fracture load first decreases and then increases. In fact, this description is a justification for fracture behavior of the Key-BD specimens under compressive-shear loading.

The experimental fracture loads were predicted by means of the two energy-based criteria, namely the ASED and ASED-EFC criteria. It was found that both criteria could successfully predict the experimental results.

References


5- Conclusions

Mixed mode I/II brittle fracture were investigated in key-hole notched specimens both experimentally and theoretically.