EXPERIMENTAL AND NUMERICAL INVESTIGATION OF MODE I FRACTURE IN PLATE PMMA SAMPLES WITH NOTCHES

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1. Introduction

A shape, loading and operating conditions, a type of material are only few of many factors which are having influence on the fracture process. Experimental studies allow to get to know the nature of the phenomenon and to build numerical models for cracking process predictions. Many papers show results of experimental studies, in which polymethyl methacrylate (PMMA) samples were often used. This thermoplastic polymer is highly sensitive to temperature changes and deformation speed. It manifests typically brittle properties during dynamic tests or at low temperatures [1]. Experimental fracture investigations were carried out in different conditions. Flat elements usually were tested under tension [2] and compression [3], less often under torsion [4]. Samples had form of: discs, semi-circular discs, blocks, beams et cetera. Researchers used sharp or small radius rounded notches, so they always received linear stress-strain curves. Strong stress concentrators, accelerate the fracture process (below the yield point). During experimental studies, authors determined basic cracking parameters: the critical load value, the initiation angle and the initiation place.

Based on the empirical results, numerical analysis were conducted. In most of them, the finite element method or the boundary element method were used. Most of numerical models consist of 2D elements, assuming the plane stress. Any analysis of stress and strain distributions on a sample thickness, do not existed. Calculations simplified using a linearly elastic material model. Distribution of stress and strain fields and their variability is important during the construction and the verification of fracture criteria.

2. Experimental study

Transparent PMMA samples were used. Flat elements had two thicknesses (9.7 and 18 mm) and they were weakened by two types of edge-notches: a rounded V-notch with a root radius 0.5 mm and a U-notch with a radius 10 mm. Monotonic tensile tests were conducted at room temperature under displacement control (0.02 mm/s), which was measured by the axial extensometer INSTRON 2620.601 with 25 mm of a gauge. The dynamic biaxial MTS 809.10 test machine was used. Load-displacement curves were recorded. They are close to linear for V-notched specimens but for U-notched they are strongly nonlinear. The critical value of load was measured. The initiation place was indicated on the fracture surface. It always appears in the notch tip and near to the middle of sample thickness. The fracture process was recorded by high-speed camera PHANTOM v1610/96 (recording speed: 200 000 frames per second). These photos were helpful to measure the initiation angle (Fig. 1).

Fig. 1. Crack evolution in V-notched samples with thickness 9.7 mm (recording angle -15°).

Firstly, the increase of crack length at time was estimated. Next a crack propagation velocity was described. The maximum value of velocity was 850 m/s for V-notched and 1120 m/s for U-notched specimens. Definitely, the fracture process was faster in samples weakened by U-notches. In thick elements crack tip had lower velocities.

3. Numerical study

In order to describe the stress and strain fields distribution, the finite element method was used (MSC. MARC). Numerical models consisted of three-dimensional isoparametric elements (HEX8). Based on a geometry and load symmetry, only 1/8 of the sample was used. A material was described by elastic-plastic model with isotropic hardening (Huber-von Mises condition of plasticity). The good agreement of numerical and experimental data was obtained. As a results of MES analysis Authors got stress and strain field distributions under critical loading conditions. The influence of notch shape and sample thickness was investigated. The maximum principal stress, equivalent stress, maximum principal plastic strain and equivalent plastic strain were presented in distance from the notch tip and sample thickness functions. New form of fracture criterion for PMMA was proposed. It was build on stress-strain relationship [5,6].

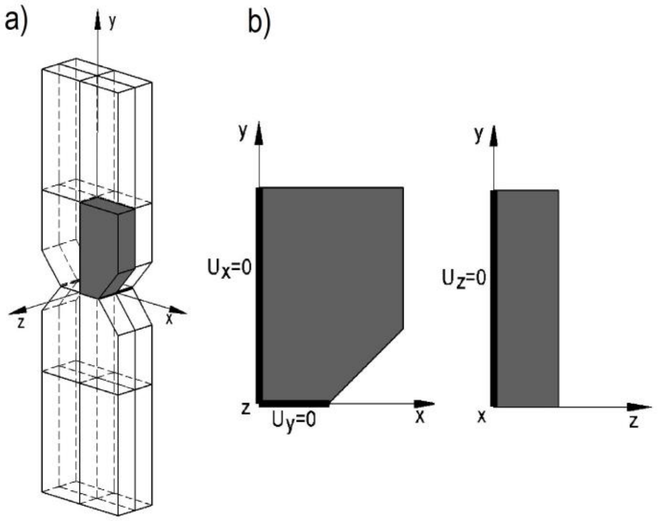

Fig. 2. Boundary conditions and loading a) b); finite element meshes c) d).

4. References

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