MECHANICS OF THE INTERACTION OF TWO PARALLEL, SIMULTANEOUSLY GROWING CRACKS USING LEFM

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Abstract

Experiments and numerical simulations studied the mechanics of two interacting colinear and offset cracks. Quasi-static experiments were carried out on acrylic sheets to determine the crack growth direction in the specimens with double parallel cracks or a single crack. The Finite Element Method (FEM) was adopted to calculate stress intensity factors at the crack tips. The interaction and influence of crack growth and direction of propagation with various geometries of cracks and their positions were discussed. This interaction is observed through a change in the propagation directions of crack tips. As the cracks grow, the SIF at the crack tip continuously increases. When the cracks are very close, SIF sharply increases for the colinear case. Crack growth behavior is observed, and the stress intensity factor is calculated at each step of crack growth for both cracks. The interaction effect on the crack path during propagation in simulation is predicted by the Maximum Tangential Stress (MTS) criterion. Some experiments are conducted to validate the analysis results. Comparisons are also made with experiments conducted under this study.

1. Introduction

Multiple cracks can be found in many engineering structures, such as aircraft, nuclear reactors, boilers, pressure vessels, and pipes[1]. In designing these structures, the analysis of multiple cracks has become increasingly significant. During the growth of multiple cracks, the coalescence causes a sudden increase in crack size, accelerating the crack growth[1]. The growth caused by coalescence dominates the growth caused by individual cracks[1,2]. The interaction of these cracks generally leads to significant structural failure. Melin[3] explains the stability of the path of multiple cracks. The mechanics of two parallel simultaneously growing edge cracks and crack path simulations by FEM in the context of brittle material have not been extensively investigated.

2. Results

a) Experiments

The experiments are carried out on acrylic plate tensile specimens. Fig. 1 illustrates the specimen's geometry, containing a double-edged crack of length a. The spacing between cracks is defined as H. The loading direction is perpendicular to the cracks. The dimensions comply with ASTM D638-14 specifications. The specimen is gripped by wedge grippers and loaded vertically as shown in Fig. 2. The experiments were performed on a Zwick/Roell 50 kN UTM machine. The test is performed at a quasi-static strain rate of 1.01×10^{-5} s^{-1}**.** In the cases of H/W = 0 and H/W = 2/13, both edge cracks propagated through the specimens and coalesced during the experiment. In the cases of H/W = 4/13 and H/W = 6/13, only one edge crack propagated through the specimens and the other remained the same during the experiment. Acrylic material specimen exhibits dynamic crack propagation. Fig. 3 shows experimental results of ultimate tensile strength for different values of spacing between cracks.

b) Numerical simulations

The numerical simulation is performed to assess the multiple parallel crack propagation process under LEFM conditions. Abaqus/CAE software predicts the growth of quasi-static cracks using the FEM, considering the mechanical parameters of the fracture. In most engineering applications, mixed-mode loading takes place. Under mixed-mode loading, the crack will not follow its original direction. Crack growth direction is predicted using three primary criteria in LEFM. The MTS criterion predicts the crack path in numerical analysis. The initial crack is modelled as a slit crack with a 2 mm initial crack length in this simulation. With a 0.5 mm increment size, quasi-static crack propagation takes place.

3. Conclusions

The interaction between two parallel edge cracks was analysed based on stress field analysis. The following conclusions were drawn from the observations:

a. The crack's relationship, shown by the crack offset distance *H* and the crack inclinations about the loading direction, significantly impacts the crack propagation direction in Fig. 4.
b. The influence can be divided into crack coalescence and interaction based on numerical analysis and experimental observations of the crack interaction under quasi-static loading. The relative crack position factors can also indicate the crack behavior.
c. Crack coalescence phenomena are observed experimentally for *H/W*= 0/13 and *H/W* = 2/13 cases. However, crack interaction occurs in experiments for both *H/W* = 4/13 and *H/W* = 6/13 cases.

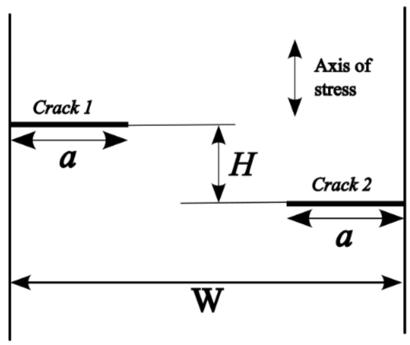

Figure 1 The geometry of two parallel cracks in the specimen subjected to tensile loading

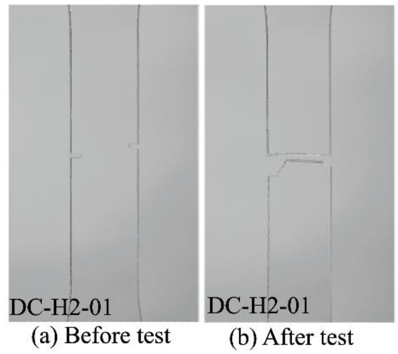

Figure 2 Photographs showing crack growth directions in a double edge crack specimen (*H* = 2 mm)

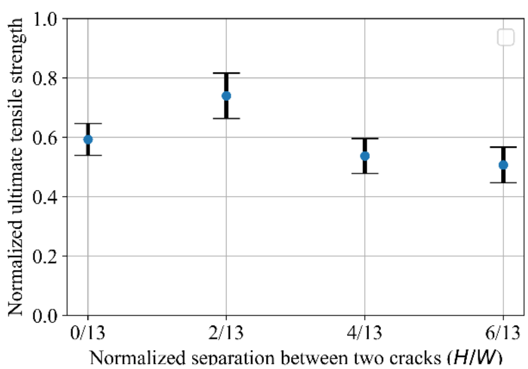

Figure 3 Experimental results of ultimate tensile strength for different value of spacing

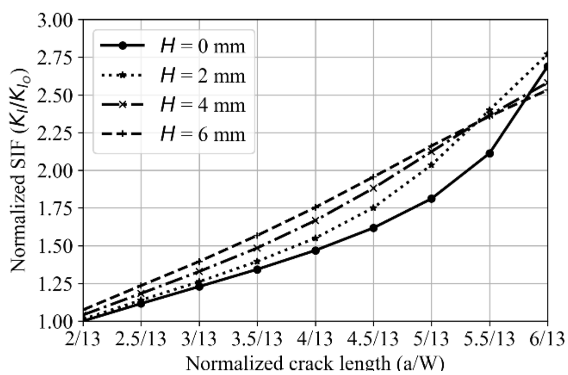

Figure 4 Normalized SIF for different value spacing between cracks *H* along the crack growth

Reference

[1]. Kamaya, M. "Growth evaluation of multiple interacting surface cracks. Part I: Experiments and simulation of coalesced crack." Engineering Fracture Mechanics 75.6 (2008): 1336-1349.
[2]. Lam, K. Y., and S. P. Phua. "Multiple crack interaction and its effect on stress intensity factor." *Engineering Fracture Mechanics* 40.3 (1991): 585-592.
[3]. Melin, S. "Why do cracks avoid each other?." *International Journal of Fracture* 23.1 (1983): 37-45.