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A numerical and experimental study of the dynamic propagation of two cracks in a brittle material

*** David Grégoire, Julien Réthoré, Hubert Maigre, Alain Combescure**

Mechanics Laboratory Contacts and Structures
LaMCoS, INSA-LYON, CNRS UMR5259
20, Avenue Albert Einstein F69621 Villeurbanne, France
david.gregoire@insa-lyon.fr - http://lamcos.insa-lyon.fr

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ABSTRACT

This paper is devoted to the numerical and experimental study of the dynamic propagation of two cracks in a brittle material. Two cracks dynamic fracture experiments are performed on polymethylmethacrylate (PMMA) in which mode combination changes and crack arrest phases occur. These experiments are then numerically reproduced by using eXtended Finite Element Method (X-FEM) in order to validate the algorithms and the criteria assumed.

Dynamic crack growth criteria

Since the tested material shows a brittle fracture behavior under dynamic loading, the fracture phenomenon is assumed to be governed by the intensity of the hoop stress near the crack tip [1]. The propagation will not initiate since this intensity remains below a critical value: the dynamic crack initiation toughness [2]. When this initiation criterion is reached the direction of the maximum hoop stress defines the critical direction of the forthcoming propagation. A dynamic crack growth toughness, depending on the crack tip velocity, is introduced to simulate the crack growth process.

Experimental procedure

The test rig is a split Hopkinson pressure bar (SHPB). In a previous work [3], dynamic brittle fracture experiments with only one crack have been performed and the crack tip position history have been determined by standard optical tools. This experiments have been numerically reproduced and the numerical simulations fit very well the experimental crack path and the measured crack tip velocity. However, with standard optical tools, the transient propagation phases as arrest and restart, the loading rate influence as well as the interaction between two cracks cannot be studied accurately. Therefore the experimental test rig has been improved by replacing the cameras with displacement optical sensors (Zimmer). It leads to a very accurate crack tip determination and allows the study of the high transient phases of crack growth, crack arrest and crack restart.

The specimen geometry enables the conversion of the impacting compressive waves into tensile waves in the vicinity of two notches machined in such a way that mixed-mode cases and effects of crack orientation appear during the crack propagation (Fig. 1).

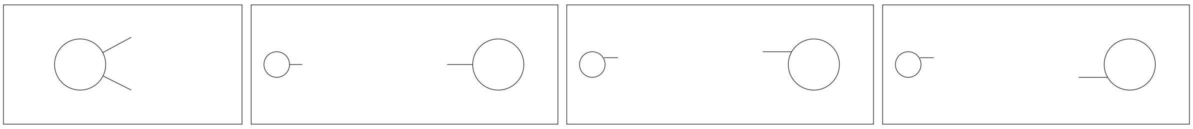

Figure 1: *Specimen geometries*

Numerical procedure

The X-FEM numerical simulations (Fig. 2) are carried out using the input velocity as a boundary condition at the input bar interface and an impedance condition is used to model the contact between the output bar and the specimen. Different phases of propagation are observed and the numerical simulations fit the experimental results.

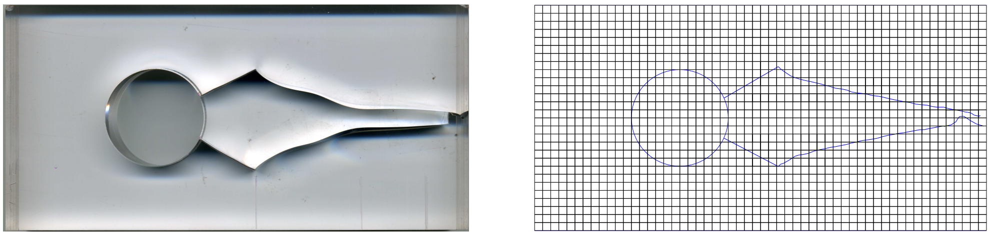

Figure 2: *Experimental and numerical crack paths for the first specimen geometry*

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