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Dynamic crack propagation on prestressed plates and pressurized vessels

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ABSTRACT

From a theoretical point of view, the speed of crack propagation is limited by the Rayleigh wave speed, approximately 3000 m/s for steel. In practice, the dynamic crack speed of ductile metallic materials is an order of magnitude lower 200-300 m/s. In this study, the dynamic crack speed on prestressed steel plates and pressurized vessels is investigated by means of numerical methods and experiments. The results shown are part of two research investigations at TNO. (i) The first aims at assessing the risk of a BLEVE (boiling liquid expanding vapor explosion) of an LPG tank. (ii) The second concerns the vulnerability of an aircraft under an internal explosion, due to for example to a terrorist attack. In either case, the time to failure and thus crack speed play a paramount role. Other possible applications of this investigation are in developing crack arresters for gas/oil pipe lines.

(i) Risk of a BLEVE on an LPG tank:
BLEVES are triggered by a crack that runs through a pressurized vessel. If the crack speed is slow and/or the rupture process of the vessel takes some time (order of 1 second), the mass flow that evaporates is limited and there is no risk of BLEVE. Yet, if the crack speed and vessel rupture are fast enough, there is a high risk of BLEVE [1]. The experiments on pre-stressed plates (Figure 1), try to represent the state of a pressurized tank. A crack is initiated by shearing the plate using a small explosive charge, which will propagate across the plate length in an unstable fashion.

(ii) Vulnerability assessment of an aircraft under an internal explosion:
To represent the stress state of a fuselage, a small scale experiment of an aluminum barrel under an internal pressure is performed (see Figure 2). Crack initiation and propagation is initiated in the same fashion as above describe, i.e. with an explosive charge.

In both experiments, the speed of crack propagation is monitored. These experiments are complex to simulate, since they involve three coupled problems: computational fluid dynamics, large deformation mechanics, and fracture. Due to the highly dynamic nature of the fracture process, an explicit finite element solver is used [2]. Cohesive elements are placed along the crack path. The analyses show the dependency between the crack speed and fracture toughness, the prestress level, the notch length, etc. Discrepancies

between experiments and simulations are used to explain the possible flaws of some of the existing cohesive zones models.

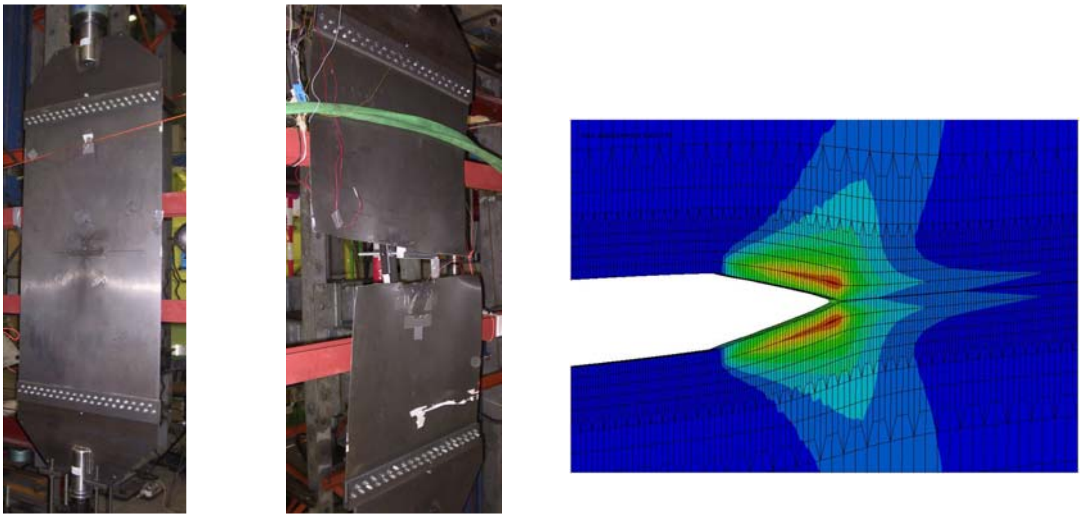

Figure 1 Tensile test stetup to measure the crack speed of a prestressed steel plate. (left) before crack propagation; (middle) after crack propagation; (right) FE model with cohesive elements, stress field at the fracture process zone.

Figure 2 Failure of an pressurized aluminum barrel. (left) setup with measuring devices, (middle) barrel after explosion; (right) FE model, stress field during crack propagation.

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