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Ignition of high explosive induced by dynamic shear banding: computational impact engineering and experimental validation

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ABSTRACT

High explosive structures may unintentionally ignite and transit to deflagration or detonation, when submitted to mechanical loadings, such as low velocity impacts (Figure 1). Safety analyses of handling these structures during transport, storage, assembling or disassembling, must take into account such low velocity impact scenarii. Unfortunately, the numerous parameters, like projectile and target geometries, initial mass and velocity, diameter of the impact area and confinement strength, prevent us from dealing only with experimental techniques.

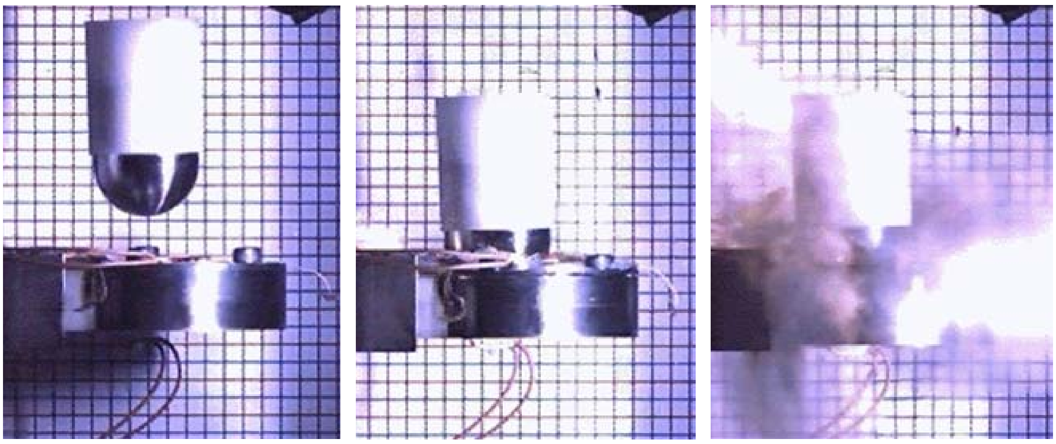

FIG. 1 – High speed recording of an impact test (the high explosive sample is confined inside the target): before impact, during impact and the beginning of the accidental reaction.

We focus our attention on ignition, the first undesirable phenomenon that must be correctly predicted by a computational safety analysis. The mechanical, thermal and chemical mechanisms at work at the microstructure scale are embedded in an ignition criterion based on the work of Browning and Scammon [1]. This criterion relies on the relevant computation of the macroscopic pressure and the macroscopic plastic shear rate inside the high explosive, seen as a continuum. The implementation of this ignition criterion, involving a non integer time integration, approximated by a Prony series with a specific spectral discretization [2], is also discussed.

Effort has been spent on modeling the behavior of the high explosive, under potentially high confining pressure and high strain rate. In this work, a concrete like behavior law is derived, with an up-to-date experimental characterization, involving pressure dependent plasticity with dilatancy.

Previous studies [3] have shown that explicit finite element technology is well suited for the investigation of high explosive structures under dynamic loading and finite strain. In this work, we present a new experimental device (Figure 2), basically derived from the so-called Steven test (Figure 1), which has been widely used as a first validation test case. This new device consists of a nearly flat nosed projectile impacting a cylindrical target containing the high explosive sample. The confinement of the target is perfectly fulfilled with some metallic parts, except for a transparent back window, which allows high speed image recording [4]. The most substantial improvement is the metallic part that can easily penetrate the high explosive sample under the impact.

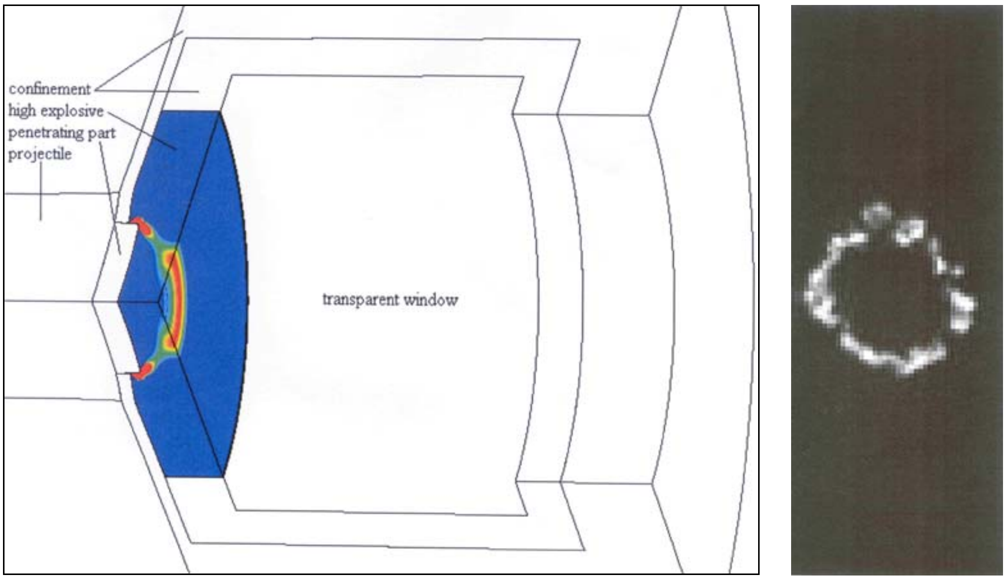

FIG. 2 – Penetrating test case: computational result and experimental ring shaped ignition.

The major experimental result is that such a penetrating impact leads, for the very first time, to a ring shaped ignition (Figure 2), fairly well predicted by the computation. Contrarily to the traditional Steven test, the computational result shows that ignition is not diffuse but localized within the main shear banding area, for which several numerical localization limiters are compared.

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