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STATISTICAL FRAGMENTATION OF HETEROGENEOUS CERAMICS

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ABSTRACT

Ceramic materials are increasingly used in engineering applications involving high strain rate loadings. A relevant example is armour ceramics for protection against blast loading and ballistic impact. Usually these extreme loadings result in the rupture of the structure in a large number of small pieces. Fragmentation is a complex and non-deterministic phenomenon which remains misunderstood. Inherent defects in the ceramics affect the process. In quasi-static loading, Weibull theory justifies that the structure breaks into few pieces, as fracture starts at the weakest links. Under high strain-rate loadings, numerous cracks initiate and propagate at seemingly random locations leading to complex stress-waves interactions.

The last decades have produced a large amount of study in this field. Mott studied the explosion of shells and focused on the one-dimensional fragmentation of a dynamically expanding ring [1]. He undertook the theoretical description of the statistical fragmentation of bodies subjected to intense impulsive loads, with particular interest in characterizing the size and the distribution of fragments. Pursuing this work, Grady included the concept of statistical heterogeneity and provided an analytical formula to calculate the average fragment size [2].

In addition to those theoretical approaches, numerical models have been getting increasingly successful at predicting dynamic failure mechanisms. There, the cohesive element method takes efficiently into account crack branching and coalescence [3-4]. Benefiting from the constant raise of computational power, models are now able to include significant statistics about defects at the microstructural length scale [5-6].

Fig: Fragmentation of a ring under high loading

Despite this large body of work, our understanding of the physics of the fragmentation process is still incomplete. This study aims at proposing a statistical model for the response of heterogeneous materials. We conduct dynamically expanding ring simulations. Fragmentation is captured by recourse to irreversible cohesive interfaces. The cohesive elements fracture strengths are spatially distributed along the ring following a Weibull distribution to model flaw statistics. Moreover, the model comprises the dissipation of energy resulting from impacts between fragments.

We investigate the influence of flaw statistics on fragment sizes distributions at various strength rates. We discuss the possibility of using recovered fragment sizes to obtain, as an inverse problem, the initial defect distribution. Also, we analyse the resulting kinetic energy of fragments, which has important implications in blast mitigation. The statistical information gathered in this work can be incorporated via homogenization in macroscopic design codes.

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