Dynamic failure of materials under extreme loading conditions, the case of brittle fragmentation

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Jeudi 06 Mars 2008 à 14h00
INSA Lyon - Amphithéâtre M. Godet
Bâtiment J. d'Alembert, 18-20 rue des Sciences, Villeurbanne

The problem of fragmentation of a contiguous body subjected to intense loading has been under strong scientific scrutiny across the past few decades. Variations in fragment sizes have important implications in ballistic impact, crash performance, explosive drilling, and clustering of galaxies resulting from big bang theory, to name a few. In the case of ceramic materials, it is well known that the strength, crack initiation, and crack propagation are affected by the presence of flaws. Under high stress loads, cracks will initiate at these flaws, and potentially propagate catastrophically to cause large-scale fragmentation. Multiple cracks will initiate at seemingly random locations and material failure will occur through a complex stress-wave communication process. In this time-dependent, non-linear mechanics setting, analytical work becomes intractable. However, recent advancements in computational methods give us new hope in developing a fundamental understanding of fragmentation.

The talk focuses on the relation between material properties, defect populations, and loading parameters on fragment-size distributions (in 1D, 2D and 3D). We begin with an overview of the cohesive element approach for crack propagation, which constitutes the core technique for the obtained results. The obtained results are compared to prior analytical models and available experimental data. Current computational challenges are discussed. Based on our results, we suggest possible novel connections with experimental techniques to reveal initial defects present in brittle materials. We conclude the talk by exploring new ways of controlling fragmentation -a rather catastrophic process- and of using it to our advantage.