PhD Position:

Shock and Reshock of Porous Materials: Mechanisms of Void Closure, Re-opening, and Dynamic Spall Fracture (REVAMP Project)

Host Institution

University of Lorraine (France)
Laboratory: LEM3 (UMR CNRS 7239) – Metz

Funding: Fully funded PhD (doctoral contract, ~2300 € gross/month)
Start date: October 1st, 2026
Application deadline: May 22nd, 2026

Supervision

Prof. Christophe Czarnota (University of Lorraine)
Dr. Cédric Sartori (University of Lorraine)
International collaboration:
Prof. José A. Rodríguez-Martínez (UC3M / IMDEA Materials Institute)

Research Context

Porous metallic materials are widely used for their energy absorption capabilities in protective applications, particularly in aerospace, defense, and transportation. Under dynamic shock loading, their response is primarily governed by pore collapse, which is controlled by both the strain-rate sensitivity of the surrounding matrix and strong local accelerations near voids. These accelerations give rise to micro-inertia effects which, combined with viscoplasticity, significantly influence the macroscopic material response (Molinari & Mercier, 2001; Sartori et al., 2015, 2016; Czarnota et al., 2020; Lovinger et al., 2021; Massarwa et al., 2024).

In parallel, dynamic failure through spall fracture—resulting from tensile waves generated by reflection at free surfaces during plate impact—is also governed by micro-inertia and viscoplastic effects, and involves void nucleation, growth, and coalescence (Antoun et al., 2003; Czarnota et al., 2008; Jacques et al., 2010; Virazels et al., 2025, 2026).

While these mechanisms have been extensively studied separately, their interplay under successive dynamic loading (shock followed by reshock) remains largely unexplored. In particular, a key open question is:

> *Does a porous material densified by an initial shock behave as a fully dense material under a subsequent shock, or does it retain a microstructural memory affecting its response and failure?*

This issue is central to many applications (protection, aeronautics, defense), where materials may be subjected to repeated dynamic loading.

The project therefore aims to analyze the coupled mechanisms of:
- void closure under shock,
- reopening or nucleation of new defects under re-shock,
- dynamic fracture by spallation (spall fracture).

The approach will rely on a close coupling between analytical modeling, numerical simulations, and comparison with experimental results obtained in collaboration with Universidad Carlos III de Madrid (UC3M) and IMDEA Materials Institute in Madrid.

Objectives

The objective of this PhD is to develop a homogenized analytical model describing pore collapse under dynamic compaction, followed by possible void re-opening and spall fracture.

The model will be implemented in Abaqus/Explicit (VUMAT) in order to perform predictive simulations directly comparable to plate impact experiments.

Particular attention will be given to the analysis of free surface velocity (FSV) profiles, as macroscopic signatures of the underlying microscopic mechanisms.

Methodology

The project follows an integrated approach combining analytical modeling, numerical simulation, and experimental interaction:

- A critical review of the literature on shock, reshock, and spall fracture in dense and porous materials;
- Development of a multi-scale homogenized model incorporating micro-inertia effects and porosity evolution;
- Implementation of the model in Abaqus/Explicit (VUMAT);
- Numerical simulations of plate impact configurations under shock and reshock conditions;
- Analysis of compaction, damage evolution, and free surface velocity profiles;
- Validation through comparison with experimental results obtained at UC3M and IMDEA.

International Collaboration

The project is part of a structured collaboration with **UC3M** and **IMDEA Materials Institute**.

Research stays in Spain are planned during the PhD, allowing direct interaction with experimental campaigns and data interpretation.

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Candidate Profile

- Master's degree in Materials Science, Mechanical Engineering or a related field
- Strong background in solid mechanics / continuum mechanics;
- Experience in finite element modeling (Abaqus);
- Programming skills (Python, Fortran);
- Experience in implementing constitutive models (VUMAT/UMAT) would be highly valued;
- Interest in dynamic phenomena, multi-scale modeling, and material failure;
- Good command of English (written and oral).

Application

Please send your application as a single PDF file to:

- **Christophe Czarnota** – christophe.czarnota@univ-lorraine.fr
- **Cédric Sartori** – cedric.sartori@univ-lorraine.fr

Required documents:

- Detailed resume
- Cover letter explaining your motivation and suitability for the position
- Academic transcripts (Bachelor's and Master's)
- Names and contact details of two academic referee

References

Antoun, T. et al. (2023) Springer-Verlag New York.

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