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Carlos III de Madrid



PhD position in Marie Skłodowska-Curie ITN-ETN

The outstanding challenge in Solid Mechanics: engineering structures subjected to extreme loading conditions

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In this project we aim to train early-stage researchers in what is referred to as an outstanding challenge in solid mechanics: developing novel solutions for the analysis and design of aerospace and defense structures subjected to extreme loading conditions. Structural elements used in aerospace and defense industries are frequently subjected to a large variety of unusually severe thermo-mechanical solicitations. One easily realizes that this type of structures (e.g. components for satellites) has to be designed to sustain extreme temperatures, which may vary hundred degrees in short periods of time, and extreme mechanical loadings like hypervelocity impacts. New specific structural solutions are constantly developed to fulfill such requirements, which place these industrial sectors in the forefront of the technological innovation. We have formed a consortium composed of 3 academic and 4 industrial partners which aims at developing specific training for early-stage researchers within the field of aerospace and defense structures subjected to severe thermo-mechanical loads. The leitmotif of this ITN is to train creative and innovative researchers ready to face structural-engineering challenges which arise in the vanguard of technological innovation. OUTCOME is a unique opportunity for 8 motivated early-stage researchers that are willing to set the basis of their scientific career within the field of Solid Mechanics.

PhD Research

Dynamic damage in ductile materials accounting for micro-inertia and void shape effect

Host

University of Lorraine - Metz



Supervisors

Professor Sébastien Mercier

Professor Christophe Czarnota

Synopsis

Under impact, ductile metals face very intense loading accompanied by high strain rates and very large magnitude of stresses. For instance, during plate impact tests, the strain rate can reach 10^7 s^{-1} and the stress level can be of the order of 10 GPa. Such large loads trigger the development of damage by microvoiding. It has been shown that the local inertia plays a role in the development of microvoiding at high strain rates. Moreover, it is known that for moderate triaxiality, the shape of the cavity evolves upon the deformation process. While this experimental observation has been carefully investigated in quasi-static conditions, under dynamic loading it has raised much less attention. In this PhD research the goal is to elucidate several key points which are still under discussion: (1) in experiments, voids

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have shapes which are not spherical or spheroidals. We aim to propose a solution to *relax* the constraint of spheroidal voids by considering cylindrical voids which can be viewed as penny shape inclusions. A model will be developed and comparisons with finite element calculations will be carried out. (2) Based on 2D simulations, various loading conditions will be investigated. We will investigate the case of shear loading in which the void-shape changes upon deformation and the semi axes of the void are rotating. An important challenge consists in modeling both aspects under low triaxiality loading and high strain rates. (3) In case of spherical voids under axisymmetric loading but with various Lode parameters, it is of interest to understand how local acceleration in the matrix influences the macroscopic stress. This aspect is fundamental. Based on precise description of the acceleration field in the matrix, we will explain how the void surface is strongly influenced by the dynamic loading. For such purposes, dedicated representative volume elements containing initially a spherical void under axisymmetric loading will be simulated under constant homogeneous stress rate loading.

Research outputs

A comprehensive comparison between numerical simulations and analytical models will enable to understand the role of local inertia in the representative volume element for various loading conditions. An original model for cylindrical voids will be developed. A comparison with 2D simulation under loading with various triaxialities will permit to understand how the void shape is changing.

Multidisciplinary / intersectoral research approach:

The ESR will work at the **University of Lorraine** (in the LEM3 laboratory, Metz, France) with Professors C. Czarnota, S. Mercier and A. Molinari in order to develop the formulation of a new constitutive model to describe damage in ductile materials subjected to high strain rates with cylindrical voids. The ESR will conduct a secondment at the TECHNION where she/he will perform experiments in order to validate the constitutive model based on micro inertia. Specific RVEs will be created, some of them with few voids so that the interaction between voids could be explored. Additionally the ESR will conduct a secondment in Spain during which he/she will visit the **University Carlos III of Madrid** and **AEROSERTEC**. At the University Carlos III of Madrid she/he will model using finite element calculations the experiments developed at the TECHNION. In AEROSERTEC she/he will identify, analyze and model (real) practical applications in which ductile damage endangers the integrity of aerospace and defense structures.

Training activities

The successful candidate will have access to the PhD program of **University of Lorraine** as well as to the training activities organized within the OUTCOME consortium. These activities include, among others:

- **Attendance to the Workshop:** Extreme structural mechanics in aerospace applications to be organized by AEROSERTEC in Madrid.
- **Attendance to the Workshop:** Extreme structural mechanics in defense applications to be organized by RAFAEL in HAIFA.
- **Attendance to the course:** Horizon 2020 Proposal Development to be organized by EUROPA Media in Budapest.
- **Attendance of the course:** Damage and failure of solids subjected to extreme loading conditions to be organized by the University of Lorraine.



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- **Attendance to the course:** From PhD to Scientific Leadership to be organized by Yellow Research in Madrid.
- **Attendance to international conferences** on damage and failure of engineering materials.

Benefits

The successful candidate will be employed for 3 years and receive a grant **plus an additional mobility and family allowance** according to the rules for Early Stage Researchers (ESRs) in an EU Marie Skłodowska-Curie Actions Innovative Training Networks (ITN):

- Living allowance – 3452.1€ (per month)
- Mobility allowance – 600€ (per month)
- Family allowance – 500€ (per month – if applicable)

This amount is a gross contribution to the salary costs. Net salary will result from deducting all compulsory social security/direct taxes from the gross salary according to the law applicable to the agreement concluded with the ESR.

Additional information about the funding provided by the ITN projects can be found in: http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/main/h2020-wp1415-msca_en.pdf

Key publications

Sartori C., Mercier S., Jacques N., Molinari A., Constitutive behavior of porous ductile materials accounting for micro-inertia and void shape. *Mechanics of Materials*. 2015; 80: 324-339.

Jacques N., Czarnota C., Mercier S., Molinari A., A micromechanical model for dynamic damage and fracture of ductile materials. *International Journal of Fracture*. 2010; 162: 159-175.

Czarnota C., Jacques N., Mercier S., Molinari A. Modelling of dynamic ductile fracture and application to Jacques simulation of plate impact tests on tantalum. *Journal of the Mechanics and Physics of Solids*. 2008; 56: 1624-1650.

Czarnota C., Mercier S., Molinari A., Modelling of nucleation and void growth in dynamic pressure loading, application to spall test on tantalum. *International Journal of Fracture*. 2006; 141: 177-194.

Molinari A., Mercier S. Micromechanical modelling of porous materials under dynamic loading, *Journal of the Mechanics and physics of Solids*. 2001; 49: 1497-1516.

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Profile

We are looking for highly motivated candidates who want to pursue a scientific career in mechanical engineering (academic or industrial). An ideal candidate would have a background in mechanical or civil engineering or physics or mathematics and a strong interest in collaborating with a team working attitude in an interdisciplinary project. Good communication in English is required.

To apply for the proposed thesis in **France**, and in order to meet the specific requirements of the Marie Skłodowska-Curie funded PhDs, you must not have resided or carried out your main activity (work, studies, etc.) in **France** for more than 12 months in the last 3 years. Candidates must have a MSc degree or obtain a MSc degree by August 2016.

Applications

The candidates must provide a letter of motivation where they clearly state why, under their point of view, they should be enrolled in the OUTCOME project.

At least, one recommendation letter from the scientist/s who mentored the candidate during her/his master studies is required. The letter must clearly expose the profile of the candidate with emphasis on the qualities making her/him suitable for being recruited in OUTCOME. Additional recommendation letters from any other professor/professional will be welcomed.

We are committed to provide flexible hours and home working conditions for researchers having family obligations. The following web-site contains relevant information **related to the EU equal opportunities policy** https://ec.europa.eu/research/science-society/women/wir/index_en.html. Moreover, the web-site <http://www.partnerjob.com/> facilitates geographic mobility by providing help to find a job for an accompanying partner.

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The application period closes in June 2016

The PhD starts in September 2016