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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

Multi-scale modeling of thermo-mechanical dynamic damage in quasi-brittle materials

Host

University of Lorraine - Metz

Supervisor

Professor Cristian Dascalu

Synopsis

Quasi-brittle materials like polymers, ceramics, composites, are widely used in aerospace and defense applications (aircraft windshields, armor systems…). The application of impact mechanical loadings or thermal shocks may lead to dynamic failure of such structural components. The understanding of the failure mechanisms at different scales of observation and the prediction of the corresponding damage evolution in quasi-brittle materials is essential for the reliability of aerospace and defense structures. Over the last decades, many research contributions pointed out the important role of the evolution of micro-cracks as key mechanisms for dynamic failure of brittle materials. For instance, the creation of multiple micro-cracks under the passage of a stress wave, to an extent that depends on loading, was proposed as an explanation for the large increase in initiation fracture toughness with the loading rate.

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It has also been established that thermo-mechanical couplings play an important role in the proper description of the dynamic fracture. Abrupt changes in thermal conditions may lead to rapid failure of brittle structural components. Based on these premises, the goal of this investigation is to develop a multi-scale theoretical model to assess the interplay between micro-cracking and thermo-mechanical evolutions in dynamic fracture processes. The proposed research will take benefit from the homogenization approaches for damage developed during the last years (see section key publications.). The new model will be implemented in a Finite Element code and simulations will be performed to reproduce experimental results for which the effects of loading rates and temperature are relevant. In particular, comparisons with experiments performed on specimens with controlled distributions of micro-cracks will allow for proper modeling microstructural aspects.

Research outputs

An original **multi-scale damage model** to predict the brittle failure of aerospace and defense structures subjected to high loading rates. The model will account for dynamic evolution of micro-cracks and thermo-mechanical couplings, providing the link between failure events at different scales of observation. The implementation in a finite-element code will allow for numerical simulations of dynamic failure phenomena.

Multidisciplinary / intersectoral research approach:

The ESR will develop at the **University of Lorraine** the core of the theoretical formulation of the multi-scale damage model. This will include the homogenization analysis for micro-fractured solids leading to the new thermo-mechanical damage evolution laws and their numerical implementation in a finite element code. Moreover, the ESR will have a period of secondment at **TECHNION**, where she/he will perform dynamic failure experiments for the validation of the damage model. Additionally the ESR will conduct a secondment in Spain, where he/she will visit the **University Carlos III of Madrid** and **Airbus Aerospace & Defence.** At the University Carlos III of Madrid she/he will continue working on the implementation of the damage model into a commercial Finite Element code (ABAQUS). In Airbus Aerospace & Defence she/he will identify, analyze and model practical (real) applications in which brittle fracture causes the collapse of aerospace structures dynamically loaded

Training activities

The successful candidate will have access to the PhD program of the **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.
- **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.

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Benefits

The successful candidate will be employed for 3 years and receive a **financial package plus an additional mobility and family allowance** according to the rules for Early Stage Researchers (ESR) in the 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

Keita O., Dascalu C., François B. A two-scale model for dynamic damage. *Journal of the Mechanics and Physics of Solids*, 2014; 64: 170-183.

Dascalu C., Bilbie G., Agiasofitou E. Damage and size effects in solids: a homogenization approach. *International Journal of Solids and Structures*. 2008; 45: 409-430.

Dobrovat A., Dascalu C., Hall S. Computational modeling of damage based on micro-crack kinking. *International Journal for Multiscale Computational Engineering*.2015; 13: 201-217.

Dascalu C., François B., Keita O. A two-scale model for subcritical damage propagation. *International Journal of Solids and Structures*. 2010; 47: 493-502.

François B., Dascalu C. A two-scale time-dependent damage model based on non-planar growth of micro-cracks. *Journal of the Mechanics and Physics of Solids*. 2010; 58: 1928-1946.

Wrzesniak A., Dascalu C., Bésuelle P. A two-scale time-dependent model of damage: influence of micro-cracks friction. *European Journal of Mechanics* A Solids. 2015; 49: 345-361.

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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 good background in mechanical or civil engineering, physics or applied mathematics, with strong analytical and computational skills and with interest for collaborating in an interdisciplinary project with a team-working attitude. 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, the candidates must not have resided or carried out their main activity (work, studies…) 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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Contact details

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The application period closes in June 2016

The PhD starts in September 2016