OUTCOME

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

Crack - flaws interactions in brittle materials under dynamic loading

Host

Technion - Haifa
Israel Institute of Technology

Supervisors

Professor Shmuel Osovski

Synopsis

Brittle (or quasi-brittle) materials are frequently used for impact-loaded components. **Dynamic crack growth in brittle materials**, is largely dominated by the interaction of the growing crack with pre-existing flaws, such as voids and micro-cracks, as well as the evolution of the later under the applied load and the interactions among them. The evolution of pre-existing flaws, as well as the creation of new ones, was proposed to be responsible for a large portion of the excess energy dissipation in the dynamic case compared to quasi-static fracture. Micro-branching, which result from crack tip instabilities were also reported to act as an additional energy dissipating process in brittle fracture of fast growing cracks. In this regard, an open question remains: *what is the effect of the initial population of flaws, in terms of size and spatial distributions, on the dynamic fracture process?* The goal of this

research is to study the interaction of a dynamically loaded mode I crack with an existing distribution of flaws (damage). Using sub-surface laser engraving techniques, we will generate controlled distribution of voids and microcracks ahead of the initial notch in a dynamic mode I specimen. The specimen, recently developed by the TEHCNION-team, allows for the propagation of a mode I crack under a large range of loading rates and large distances (up to several cm). By measuring the roughness of the obtained fracture surfaces, we aim at identifying the correlation between the properties of the microstructural features (microvoids, microcracks) and the statistics of the fracture surface. The set of experimental results produced here will serve to understand the correlation between distribution of flaws and toughness as well as fracture surface roughness, thus providing a tool not only for calibrating brittle damage/fracture models but also for their validation and evaluation.

Research outputs

A new experimental method to study the interactions between a growing crack in brittle media and the field of flaws spread ahead of it. The experimental observations are expected to yield a correlation between dynamic facture toughness, initials microstructure and fracture surface roughness. A re-examination of existing models for dynamic crack growth in brittle materials will be conducted, and their sensitivity will be evaluated based on the models ability to produce the right crack path and fracture surface roughness. Finally, specific flaws fields will be generated to demonstrate the ability of engineering a structure to direct a growing crack a way from regions which are desired to remain damage free.

Multidisciplinary / intersectoral research approach:

The ESR will develop at the TECHNION an experimental campaign of unprecedented magnitude to show the interplay between the propagation of cracks in brittle media and the material flaws. Moreover she/he will conduct a secondment at the **University of Lorraine** where she/he will develop a model to describe the observed experimental results on the interaction between flaws and a dynamic crack.. 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 implement the proposed damage model into a commercial Finite Element code (ABAQUS) for purposes of comparing the predictive power of the model with respect to the experimental data. In Airbus Aerospace & Defence she/he will identify, analyze and model (real) practical applications in which material defects cause the development of damage and subsequent failure of aerospace (brittle) structural materials.

Training activities

The successful candidate will have access to the PhD program of the **TECHNION** 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 prestigious international conferences** on damage and failure of engineering materials.

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 (ESRs) in an EU Marie Skłodowska-Curie Actions Innovative Training Networks (ITN):

- Living allowance – 3380.57 € (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

Ravi-Chandar K., Yang B. On the role of microcracks in the dynamic fracture of brittle materials. *Journal of the Mechanics and Physics of Solids*. 1997; 45: 535-563.

Rittel D., Maigre H. An investigation of dynamic crack initiation in PMMA. *Mechanics of Materials*. 1996; 23: 229-239.

Ravi-Chandar K., Knauus W.G. An experimental investigation into dynamic fracture: II. Microstructural aspects. *International Journal of Fracture*. 1984; 26: 65-80.

Osovski S., Srivastava A., Ponson L., Bouchaud E., Tvergaard V., Needleman A. 2014. Effect of loading rate on ductile fracture roughness and toughness. *Journal of the Mechanics and Physics of Solids*. 2014; 76: 20–46.

Osovski S., Srivastava A., Williams J. C., Needleman A. Grain boundary crack growth in metastable titanium β alloys. *Acta Materialia*. 2015; 82: 167-178.

Shukla A. Interaction of an explosively driven crack with a large flaw. *ICF6*, New Delhi (India) 1984.

McCauley J.W., Strassburger E., Patel P., Paliwal B., Ramesh K. T. Experimental Observations on Dynamic Response of Selected Transparent Armor Materials. *Experimental Mechanics*. 2013; 53:3-29.

Hu G., Liu J., Graham-Brady L., Ramesh K.T. 2015. A 3D mechanistic model for brittle materials containing evolving flaw distributions under dynamic multiaxial loading. *Journal of the Mechanics and Physics of Solids*. 2015; 78: 269-297.

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Profile

We are looking for highly motivated early-stage researchers with the following profile:

- Hands-on mentality, good organizational and communication skills.
- Proactive attitude and ability to work both independently/autonomously and within a team.
- Excellent communication skills in English.

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 **Israel** for more than 12 months in the last 3 years. You may be of any Nationality.

Required educational level

Degree	Master degree or equivalent
Degree field	Engineering: civil, mechanical, aerospace
Degree	Master degree or equivalent
Degree field	Physics

Career stage

Early stage researcher or 0-4 years (Post graduate)

Professional and/or research experience

We will particularly consider those candidates with proven experience in technological and/or research activities. Publication/s in journals indexed in the Journal of Citation Reports will be especially welcomed.

Letter of motivation

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

References

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 in the qualities which make her/him suitable for being recruited in OUTCOME. Additional recommendation letters from any other professor/professional will be most welcomed.

Specific qualifications

Candidates should have a solid background in Solid Mechanics, Experimental Mechanics, Fracture Mechanics and Numerical Modeling.

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Flexible working conditions

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