PhD position - Hygromechanical analysis of damage in metal/composite assemblies: micro/mesoscale modelling and experimentation

Keywords

Multiscale modelling, analytical modelling, finite element modelling, micromechanics, hygro-mechanical coupling, multi-physics, advanced experiments, microtomography.

Profile and skills required

- Master degree in mechanical, structural or civil engineering.
- Strong skills in solids mechanics.
- Skills in finite element simulations (preferably with previous experience with Abaqus or Comsol Multiphysics).
- Motivation to perform modelling research.
- Motivation to perform advanced experimental tests.
- Knowledge of (or motivation to learn) micromechanics.
- Motivation to carry out fundamental research at fast pace.
- Scientific communication and advanced English.

PhD detailed overview

Many industrial sectors are exploring new materials and processes that offer high performances while reducing their energy footprint and emissions. To this aim, metal/composite structural bonding is of great interest because it guarantees a reduction of on-board weight compared to the traditional techniques, as riveting and bolting, and other advantages such as uniform stress distribution and elimination of galvanic corrosion [1]. Unfortunately, these assemblies are still not extensively used in industries for the lack of understanding and control of the phenomena involving the quality and the durability of the adhesive joint.

This PhD project will focus on the determination of the damage non-propagation thresholds in metal/composite structural adhesive joints (steel/carbon fibre-reinforced polymers, CFRP). **The main goal of the project is to analyse the initial damage and its evolution until the non-propagation threshold under the combined action of hygromechanical loadings** (multi-physics coupling [2]).
The proposed PhD position is part of the broader research project **ANR JCJC ASHENDO** (ANR-22-CE08), financed by the French National Research agency (ANR).

The adopted methodology will be interdisciplinary as it will combine analytical modelling, numerical modelling and experimental mechanics. Developed tools will be of great interest for engineers, manufacturers and scientists for the detection of the non-propagation thresholds of initial defects in multi-material bonded assemblies, in service and long duration conditions, in environments with high humidity variations.

The PhD project is organized in three main tasks:

- **Task 1. Modelling and characterization at the microscale.** This task is devoted to experimentally characterize and modelling the main microscopic aspects influencing the damaging behaviour of the metal/composite bonded assembly. Emphasis will be placed on the influence of the **initial porosity in the adhesive** [3] and on the behaviour of **the adhesive/substrates interface** [4].

- **Task 2. Modelling and characterization at the mesoscale.** This task is devoted to build a numerical representative elementary volume (NREV), in the FE method framework, of the adhesive bonded zone. Modelling and experimental data obtained at the microscale (Task 1) will be implemented in the NREV. Experimental characterization at the mesoscale will be also carried out and compared to the numerical model.
- **Task 3. Build an open database on hygromechanical properties of adhesive joints.** This task is devoted to gather all the experimental and calculated data (available in literature and obtained during the project) on standard mechanical properties (i.e. stiffness, strength, ductility, etc.) of adhesive joints in relation with the porosity rate, RH conditions and surface roughness. The database can be interrogated via machine-learning techniques in order to discover correlations between the composition, processing, properties and performance of this kind of assemblies. For this task, the PhD candidate will participate at the supervision of ISAE-Supméca master projects (100-150h) dedicated to the database construction and online production, with the support from our colleagues of team Sustainable Systems at Quartz laboratory concerning machine-learning.

Supervision

Supervision by M. L. Raffa (associate professor), O. Klinkova (full professor) and T. Da Silva Botelho (full professor) of ISAE-Supméca and Quartz laboratory, Tribology and Materials team.

Financial support

Financial support of the French National Research agency (ANR) via the project **ANR JCJC ASHENDO** (ANR-22-CE08). The participation in national and international conferences (2 to 3) is comprised.

Salary: Net salary of about 2000€/month.

Duration: 3 years, starting in Fall 2022.

Localisation: The research work will be mainly carried out at the Quartz laboratory on the ISAE-Supméca site (Saint-Ouen-sur-Seine). An experimental campaign concerning microtomography in collaboration with the Laboratory of Mechanics and Acoustic of Marseille is planned (all relative costs are comprised in the financial support).

To apply: Please send CV, transcripts and motivation letter to the contacts below.

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References

[1] Arenas, J. M., Alía, C., Narbón, J. J. *et al.* (2013). Considerations for the industrial application of structural adhesive joints in the aluminium–composite material bonding. *Comp. Part B: Eng.*, *44*(1), 417-423. doi.org/10.1016/j.compositesb.2012.04.026

[2] Kessentini, R., Klinkova, O., Jrad, H. *et al.* (2018). Analytical and numerical investigation of coupled hygro-thermo-mechanical model of multi-layers bonded structure. *Int. J. Adh. Adhes.*, *84*, 108-118. doi.org/10.1016/j.ijadhadh.2018.02.031

[3] Dumont, V., Badulescu, C., Stamoulis, G. *et al.* (2020). On the influence of mechanical loadings on the porosities of structural epoxy adhesives joints by means of in-situ X-ray microtomography. *Int. J. Adh. Adhes.*, *99*, 102568. doi.org/10.1016/j.ijadhadh.2020.102568

[4] Hirsch, F., Natkowski, E., Kästner, M. (2021). Modelling and simulation of interface failure in metal-composite hybrids. *Comp. Sci. Tech.*, 214, 108965. doi.org/10.1016/j.compscitech.2021.108965