



OPIN Workshop

Advanced Materials and Manufacturing (Composite focus)

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Latest news from the academic
research

OUTLINE

- GeM/E3M team competencies and objectives
- GeM/E3M team testing facilities
- Examples of relevant R&D projects
- Collaborations wishes

GeM/E3M team competencies and objectives

Global thematic : durability of materials

Characterization and modeling of hygro-thermo-mechanical behavior of composites in harsh environment

→ Robust predictive tools for structural design and/or risk-based maintenance optimization



Research team skills :

- ☐ Multi-physics and multi-scales modeling
- ☐ Experimental characterization
- ☐ Hygro-mechanical couplings
- ☐ Variability and uncertainties

Application areas :

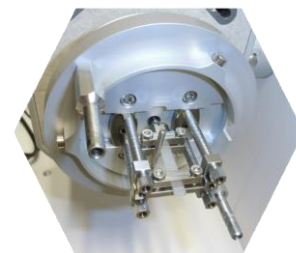
- ☐ MRE structures
- ☐ Automotive industry
- ☐ aeronautics

Studied materials :

- ☐ Thermoset and thermoplastic composites
- ☐ Sandwich structured composites
- ☐ Natural fiber composites
- ☐ Multi-materials with bonded joint

GeM/E3M team testing facilities

- ❑ **Climatic chambers** : hygro-thermal controlled environment for kinetics of diffusion
- ❑ **Dynamical Mechanical Analysis (DMA)** : characterization of visco-elastic properties
- ❑ **Dynamic Vapor Sorption (DVS)** : measurements of water sorption isotherms
- ❑ **Scanning Electron Microscope (SEM)** : microstructure studies (crack, porosity etc.)
- ❑ **Differential Scanning Calorimetry (DSC)** : measurements of glass transition temperature
- ❑ **Cone calorimeter** : characterization of fire behavior under mechanical loadings
- ❑ **HPC computers** : intensive computation
- ❑ **X-ray diffraction** : measurement of crystallinity of natural fibers
- ❑ Development of **specific experimental devices** (optical fibers measurements, fatigue/creep tests, etc.)

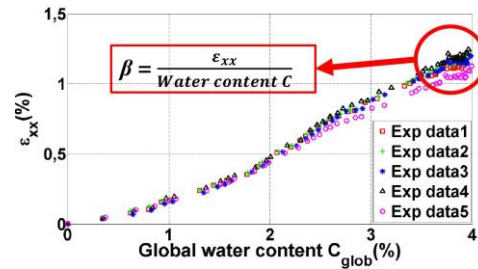
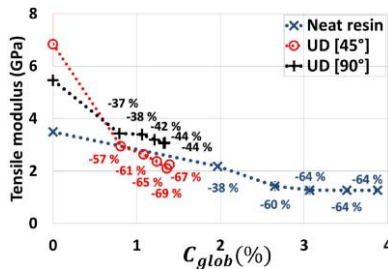


Examples of R&D projects

STIICPA project (ADEME funding 2013-2016)

→ Characterization and modeling of hygro-elastic coupling (glass/PA6 composites)

Experimental observations



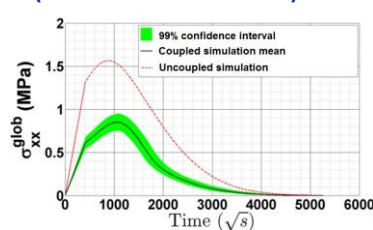
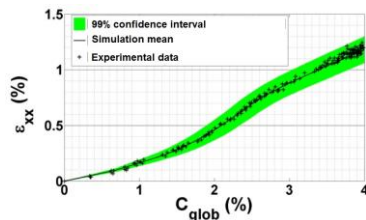
→ Nonlinear evolution of elastic modulus and swelling coefficient

Key points

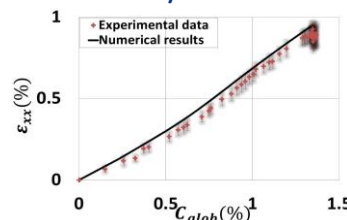
- ❑ Development of adapted nonlinear local models
- ❑ Identification with inverse problem using parametric/stochastic approach
- ❑ Probabilistic modeling

Significant results

Neat resin results (strain and stress)



Glass/PA6 results



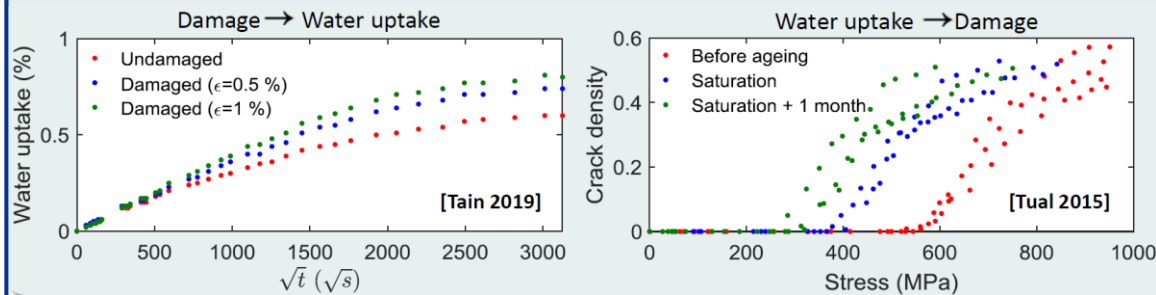
→ Good behavior of the proposed nonlinear model for both neat PA6 and composite cases

Examples of R&D projects

FIRMAIN project (WeAMEC funding 2016-2019)

→ Modeling of aging impact on local damage of composite materials

Experimental observations

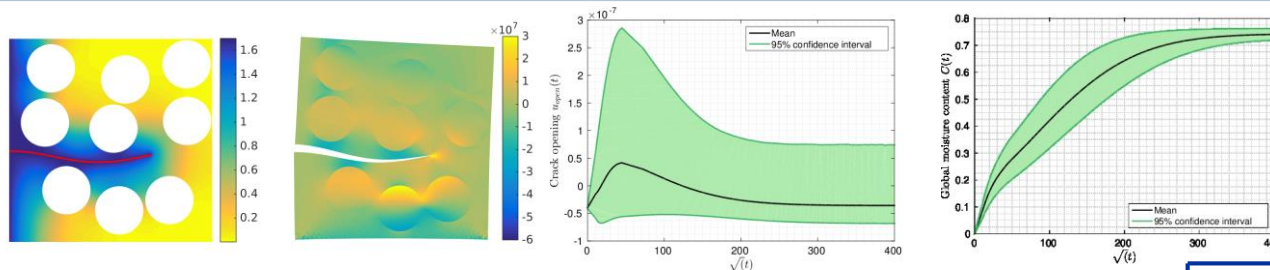


→ Faster diffusion with damage and damage increase with aging

Key points

- ☐ X-FEM methodology for crack modeling
- ☐ S-FEM methodology for variability
- ☐ Impact of edge crack on moisture diffusion

Significant results



Local moisture and stress fields

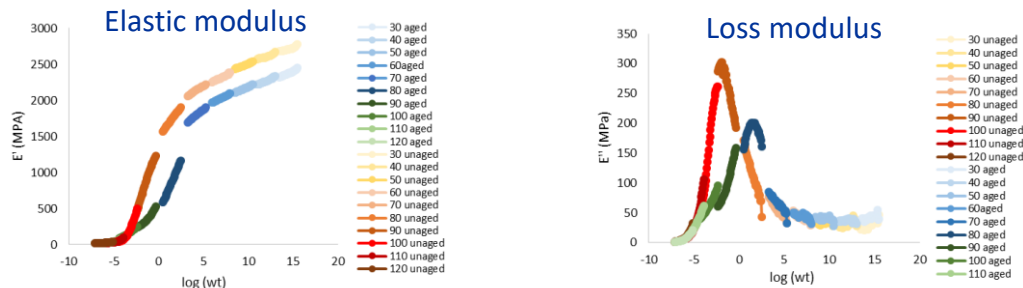
Stochastic processes

→ Access to micro/macro scales results with uncertainties

CEAUCOMP project (WeAMEC/ONR funding 2018-2021)

→ Characterization and modeling of hygro-visco-elastic behavior of composite materials

Characterization for unaged and aged samples (DMA)



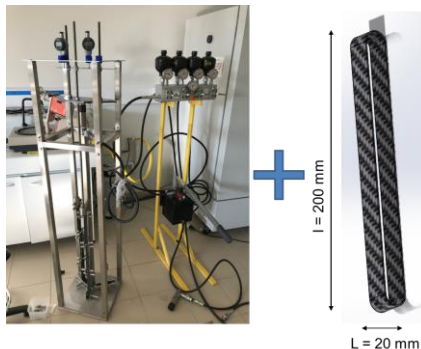
→ Evolution of elastic modulus and viscosity with aging

Key points

- ☐ Characterization of moisture diffusion impact on visco-elastic properties
- ☐ Development of adapted hygro-visco-elastic model
- ☐ FEM modeling of creep tests under aging with experimental comparisons

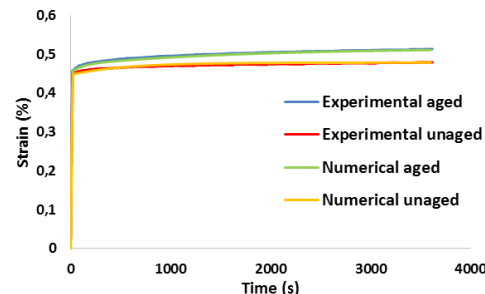
Preliminary works and results

Specific device development



→ Avoid grip problems in wet case

First simulations based on Maxwell model



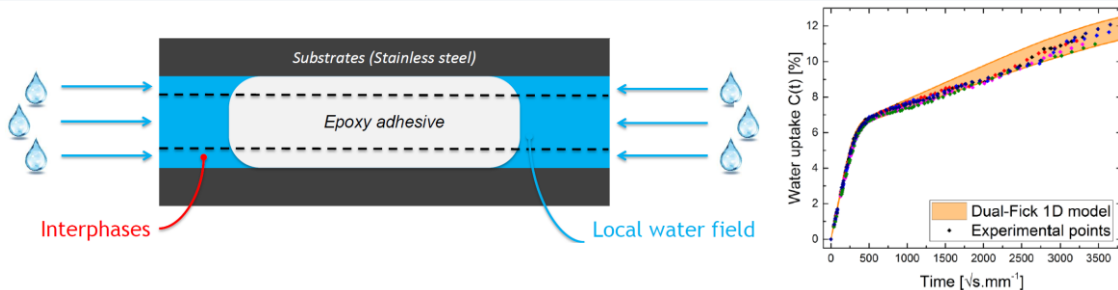
→ Allow simulating the effect of aging

Examples of R&D projects

INDUSCOL project (ANR/FEM funding 2016-2020)

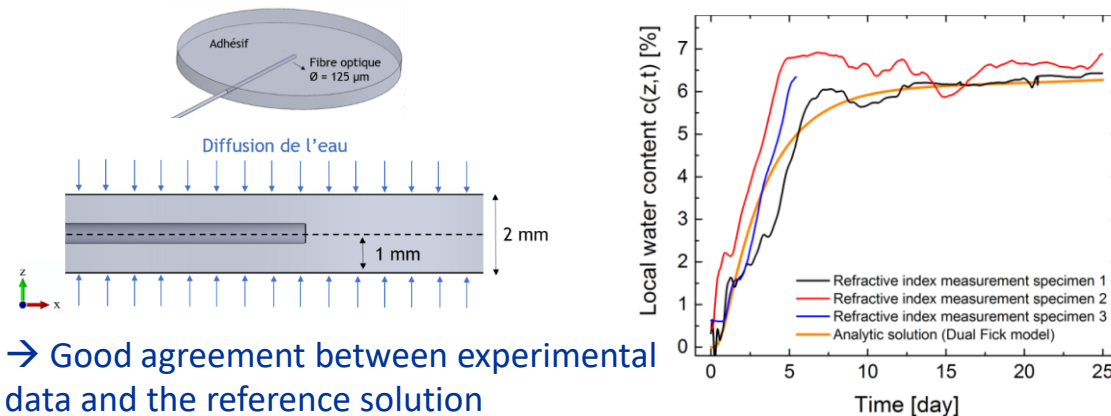
→ Durability of assemblies with bonded joint in humid environment

Experimental observations and needs



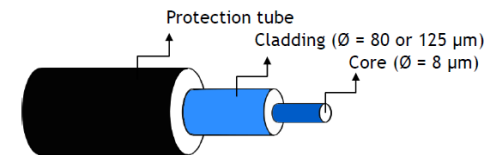
Very hydrophilic bulk adhesive → possible decay of the adhesive

Significant results



Key points

- Development of specific optical sensor to monitor the local moisture content



- Identification of local moisture content on site
- Characterization and modeling of interphases
- Approach based on gradient model

Collaboration wishes

What should be investigated in the future according to us?

- ☐ Damage:
 - studying the impact of aging on **debonding** at the matrix/fiber interface (experimental observations and modeling)
 - Setting up **experimental tests** for matrix crack propagation and delamination (static and cycling loadings)
- ☐ Cycling: studying and understanding the impact of diffusion cycling on the hygro-elastic behavior (ex: diffusion properties changes) with **thermodynamical models** to improve reliable predictions
- ☐ Bonded assemblies: improving optical sensors (**biaxial measurements**) and extending its use for **mechanical fields measurements** and for composite materials
- ☐ Coupled problems with nonlinear behaviors: studying the impact of aging on **properties of nonlinear behaviors** such as viscoplasticity

Thanks to all my past and present co-workers

H. Obeid/S. Fréour/F. Jacquemin/A. Uguen/S. Tain/Q. Dézulier/P. Davies/M. Girard/R. Grangeat and many more

Q & A

Interreg



North-West Europe

OPIN

European Regional Development Fund

Thank you!