2nd Ifremer-ONR Workshop
"Durability of Composites in a Marine Environment"
24th- 25th August 2016, at the
Ifremer Centre in Brest, France

Characterization of composite materials ageing mechanisms in marine environment

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Context:

The renewable marine energies (RME) as tidal turbines offer considerable potential. The majority of tidal turbine developers have preferred carbon or a combination between glass and carbon blades. These structures are subject to many forces such as ocean tides, waves, storms. Despite of such **complex loads**, tidal turbine blade are also subject to various marine aggressions, such as **sea water and corrosion**. A thorough understanding of the **long term behavior** of the moving parts is therefore essential. There is a need to understand how long immersion in the ocean affects these composites.


Alstom - TGL - Rolls Royce

Objectives:

VICOMTE project is aiming to investigate and develop new methodologies in order to: **(i) study** and **(ii) model** the complex impact of sea water ageing on composites blades.

- **(i) Fast characterization method** ➡ to characterise composites behavior in marine environment.
- **(ii) Numerical developments** ➡ to establish a model coupling the **relationship between the diffusion of moisture** effects and the effects of **mechanical load** applied on composites.

Experimental accelerated methodologies

- **Time-Temperature Superposition Principle (TTSP)**
  Due to the viscoelastic behavior of the resin (temperature dependence), then TTSP is applicable to quickly predict the long-term fatigue life of such composites materials. Masters' curves will be obtain experimentally, 4-point bending quasi-static, creep and fatigue tests will be performed.

- **Experimental campaign coupled with progressive damage analysis**
  Puck's phenomenological criterion will be linked to experimental accelerated methodology for fatigue and moisture ageing
  ➡ Puck's first damage criterion will be used as the common strength criterion.

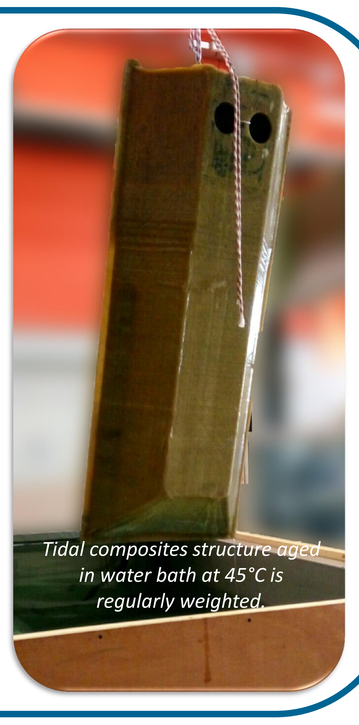
Accelerated test at different scales :

- **At specimens scale**

A pre-preg material will be water aged to study water diffusion process at different temperature. An experimental campaign will be leaded to understand the effect of water ageing and the combined effect of fatigue and water ageing on pre-preg material properties.

- **At structure scale**

Accelerated tests at structure scale have been developed to measure water ingress in large structure. This type of development will allow to validate the numerical model established.


Tidal composites structure aged in water bath at 45°C is regularly weighted.

Numerical methodologies

- **Objective**

This project aims to establish an hygro-mechanichal **coupling between the diffusion of moisture** effects and the effects of **mechanical load** applied on composites.

- **Formulation**

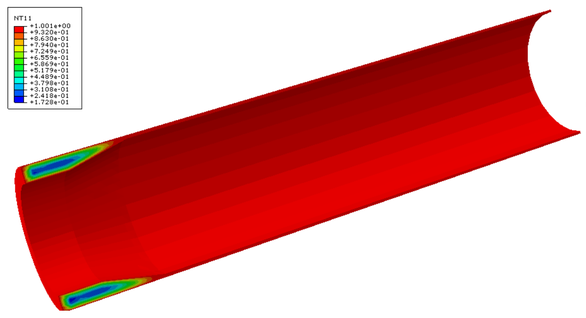
The formulation of this hydro-mechanical coupling is be based on:
➡ Empirical approaches such as the free-volume theory
➡ Incremental approach of mechanical property reduction depending on the level of water diffusion.

- **Diffusion simulation through the thickness of a blade**

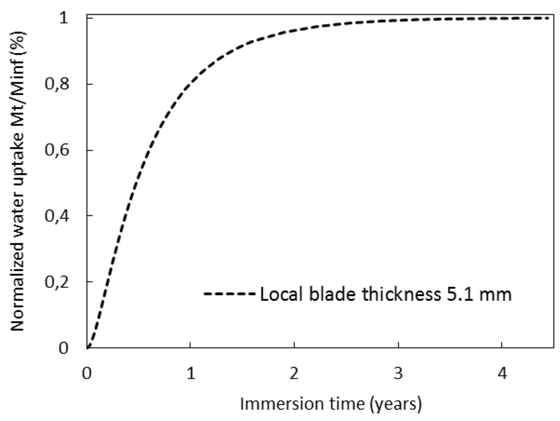
A diffusion model (Fick's Law) has been applied on large structure in order to predict long term diffusion of water :
Theses results will also allow a comparison with expermimental measurements.

Fick's Law:

$$\begin{cases} \dfrac{\partial c}{\partial t} = \nabla.(D\nabla c) \\ Boundary\ conditions : c_\infty \end{cases}$$



(a) Water diffusion modelling on a composite blade at 40°C using FE Abaqus code.



(b) Results of a local water ingress into the blade thickness.

Conclusion & perspectives:

- New **tools to evaluate the evolution of mechanical behavior of composite** materials used in RME structures.
- Study of **durability and prediction** of damage in composite materials ➡ bring new knowledge in order to have a better utilization of composites in RME.
- Methodologies developed in the VICOMTE project will be used by the different actor implicated in the development of composites parts for **underwater & REM applications** .

This poster is part of the VICOMTE project managed by IRT Jules Verne (French Institute in Research and Technology in Advanced Manufacturing Technologies for Composite, Metallic and Hybrid Structures). The authors wish to associate the industrial and academic partners of this project; respectively GE (General Electric), BUREAU VERITAS, MECA and GEM laboratory of Nantes University