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TESTING TO EVALUATE WATER EFFECTS IN COMPOSITES: A CRITICAL REGARD

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ABSTRACT

Polymer matrix composites are already widely used in marine applications, but many of these are overdesigned (glass/polyester pleasure boat hulls for example) and rarely heavily loaded. These structures can last for 30 years or more and the main issue is how to dispose of them at the end of their useful life. However, composite materials are increasingly being proposed for more highly loaded structural components such as propellers and tidal turbine blades. For these structures, the effects of seawater aging combined with mechanical loads are critical, as the commercial success of such components depends on minimal intervention and high reliability. For this type of composite the tests performed to evaluate degradation due to long term immersion are therefore critical. It is also essential to have a robust approach in order to evaluate potential alternative materials, some of which (natural fibre composite for example) show quite specific behaviour when wet. This paper will describe the current approach to account for wet aging, its limitations and some proposals for an improved testing methodology.

The simplest way to take account of water is to saturate specimens, test their properties in this wet state and apply a knockdown factor during design to account for property loss. This may be justified if the final structure is exactly equivalent to the test sample (geometry, manufacturing, defects) but provides no information on damage mechanisms and may lead to a very conservative design.

Based on the work of Springer and colleagues [1] a more rational approach has been proposed, which characterizes the diffusion kinetics in order to establish the moisture profiles within composites at a given time. Once these are known, and the relationship between water content and property loss has been established, this approach can provide a more useful prediction of the response of a composite structure as a function of immersion exposure, Figure 1

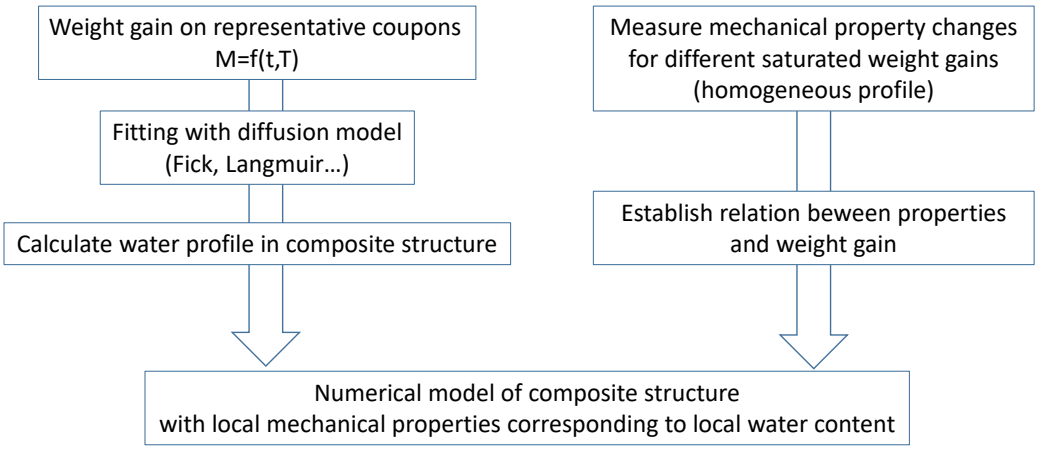

Figure 1 Methodology to quantify water aging effects on composite structures.

While this approach provides a general framework to analyse service conditions it is clearly incomplete [2]. There are several difficulties and intrinsic assumptions which need to be justified. First, it assumes that water content is the only parameter affecting property loss. Second, the timescale of water diffusion in cold water can be very long, so most published studies are based on accelerated aging lasting a few weeks or months. The validity of the changes induced by raising temperature or reducing sample thickness must be verified, and this requires detailed physico-chemical analysis. Third, coupling effects are rarely included but stress can accelerate water ingress and the presence of water can lower damage thresholds [3] and accelerate the viscoelastic response [4]. Finally, most marine structures are coated (gel-coats, anti-fouling paint layers, specific coatings), and these all affect water entry.

The presentation will be illustrated by recent results from three case studies:

- An example in which composite samples have been aged at different temperatures for over 10 years, allowing a critical evaluation of the temperature acceleration approach.
- A study based on natural fibre composites, highlighting the role of edge effects and coatings.
- Results from ongoing work to include aging in composite design, applying the methodology shown in Figure 1 to unaged and aged composites under combined flexure and shear loading.

REFERENCES

[1] Shen C-H, Springer GS (1981). *Moisture absorption and desorption of composite materials*, Chapter 3 in Environmental effects on composite materials, edited by GS Springer, Technomic, 15-33.
[2] Davies P, (2020) *Towards more representative accelerated aging of marine composites* in "Advances in Thick Section Composite and Sandwich Structures", Springer, ISBN 978-3-030-31065-3. 507-527
[3] Tual N, Carrere N, Davies P, Bonnemains T, Lolive E, (2015) *Characterization of sea water ageing effects on mechanical properties of carbon/epoxy composites for tidal turbine blades*, (2015) Composites Part A,78, 380-389
[4] Dezulier Q, Clement A, Davies P, Jacquemin F, Arhant M, Flageul B, (2022), *Characterization and modelling of the hygro-viscoelastic behaviour of polymer-based composites used in marine environment* Phil. Trans. R. Soc. A.38120210221.