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ON THE STUDY OF COUPLED CREEP TEST OF COMPOSITE MATERIAL USED IN A MARINE ENVIRONMENT

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ABSTRACT

Marine renewable energy (MRE) structures are simultaneously subjected to severe environmental conditions (water or humid air) and continuous mechanical loadings during their lifetime. These parameters accelerate the damage development [1] and it appears important to build effective predictive models which should take into account the coupled representative operating conditions of the MRE structures.
The aim of this study is to have a better understanding of the coupling between the diffusion of water and the mechanical behaviour of composite materials used in marine energy conversion systems, through both a regular campaign of uncoupled tests and also innovative experiments where creep is performed in water.
Many studies have been conducted on the impact of water diffusion on the resulting properties of composite materials, [2,3]. For instance, the hygroscopic swelling leads to significant mechanical strains and internal stresses which may cause premature damage. However, few studies have focused on the coupled phenomena. Indeed, the absorption of water has multiple effects on composite materials such as decreases of Young's modulus or glass transition temperature for instance [4] which have a direct impact on the mechanical behaviour of the studied material. Thus, there is a coupled relation between the mechanical state and the absorption of water that needs further investigation.
A first experimental campaign has been performed on both epoxy and CFRP samples to study the diffusive and mechanical behaviour at different states of ageing, for different humid conditions, written below in the table 1.

Table 1: Humid conditions of testing

	Humid condition	Epoxy resin	CFRP
Humid air	40°C 85%RH	X	
Immersion	25°C	X	X
	60°C	X	X

Through gravimetric tests, diffusive properties have been identified and linked with hygroscopic swelling coefficients to predict internal stresses caused by the water gradient inside the material (neat resin or composite).
Other mechanical tests have been performed at different stages of ageing (unaged, after 2 month, 6 months of humid ageing) to examine the evolution of elastic (uniaxial tensile tests) and viscoelastic (creep test) properties versus the global water content. Long-term creep test (over 2 months) were also realised in air and in immersion to highlight the influence of water diffusion especially on viscoelastic properties, as seen in figure 1.

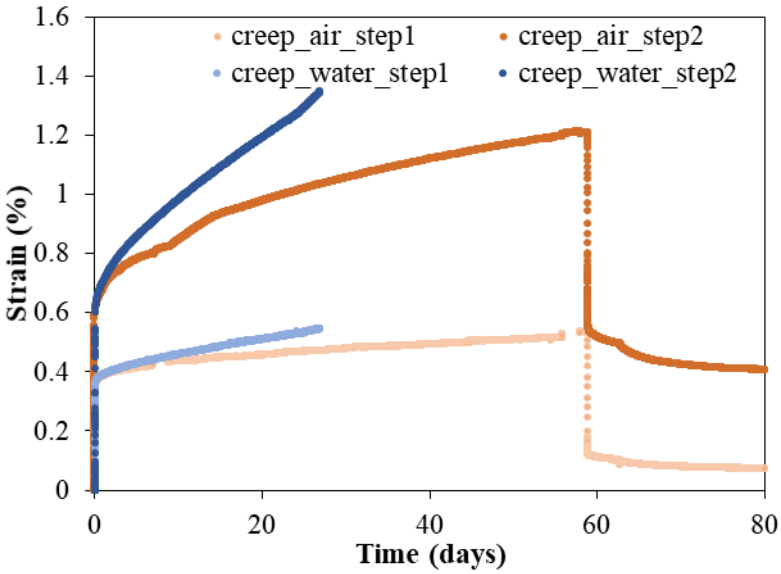

Figure 1: Long term creep test on $[+/-45]_6$ CFRP samples in air (orange) and in water (blue)

The main added value of this study is to investigate coupled creep tests in a controlled environment (immersion and humid air) on composite samples through an innovative bench test which will take account of the evolution of deformation and mass of a specific sample design [5] . This will lead not only to a better understanding of the role of the environment on the mechanical state but also to the influence of a mechanical loading on the diffusive behaviour of the material at the same time. These experimental observations and characterization will allow improved, uncoupled and coupled hygro-mechanical models to be developed; aiming at taking into account the parameters previously determined. Numerical studies based on the proposed hygro-viscoelastic models will also be presented in order to obtain local complementary results on the hygro-mechanical behaviour.

GRATITUDE
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REFERENCES

[1] D. Perreux and C. Suri, “A study of the coupling between the phenomena of water absorption and damage in glass/epoxy composite pipes,” *Compos. Sci. Technol.*, vol. 57, no. 9–10, pp. 1403–1413, Jan. 1997.

[2] C. Humeau, P. Davies, and F. Jacquemin, “An experimental study of water diffusion in carbon/epoxy composites under static tensile stress,” *Compos. Part A Appl. Sci. Manuf.*, vol. 107, pp. 94–104, Apr. 2018.

[3] G. C. Papanicolaou, A. G. Xepapadaki & D. S. Zarouchas "Effect of water uptake on creep behaviour of glass–epoxy composites", *Plastics, Rubber and Composites*, 38:2-4, 72-79, 2009

[4] E. L. McKague, J. D. Reynolds, and J. E. Halkias, “Swelling and glass transition relations for epoxy matrix material in humid environments,” *J. Appl. Polym. Sci.*, vol. 22, no. 6, pp. 1643–1654, 1978.

[5] F. Baschnagel, V. Rohr, and G. Pietro Terrasi, “Fretting fatigue behaviour of pin-loaded thermoset carbon-fibre-reinforced polymer (CFRP) straps,” *Polymers (Basel).*, vol. 8, no. 4, 2016.