Proceedings IRF2018: 6th International Conference Integrity-Reliability-Failure
Lisbon/Portugal 22-26 July 2018. Editors J.F. Silva Gomes and S.A. Meguid
Publ. INEGI/FEUP (2018); ISBN: 978-989-20-8313-1

PAPER REF: 7152

COMPARATIVE STUDY ON ACCELERATED FLUID DIFFUSION IN THERMOSET EPOXY AND GFRP FOR MARINE APPLICATIONS

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ABSTRACT

This paper presents an innovative testing methodology to evaluate the effect on Glass Fibre Reinforced Polymers (GFRPs) of long-term exposure to a simulated marine environment, typical in offshore Oil & Gas applications. The performance of material samples exposed to seawater at 25, 55, 80 °C was quantified. Gravimetric, Dynamic Mechanical Analysis and mechanical testing have been performed in parallel on progressively aged samples. Results show an exponential increase in water absorption rate with temperature. Glass transition temperature drops with the advancing of the seawater absorption. Mechanical testing demonstrated a progressive decrease in tensile strength, further reduced by the ageing that follows fluid saturation of the material.

Keywords: PMCs, fluid diffusion, ageing, accelerated testing, gravimetric, DMA.

INTRODUCTION

Polymer Matrix Composites (PMCs) are becoming more widely diffused in the Oil & Gas industry. The potential to exploit their outstanding mechanical properties, along with their reduced density compared to metals, makes them a suitable substitute to overcome the technical limitations of traditional structural alloys for deep-water fossil fuels recovery. There is not yet extensive experience with PMCs when it comes to marine applications. The qualification of composite materials for harsh Oil & Gas services is less advanced than in the aerospace industry, where specific grades and qualifying routines have been developed over many decades. Pipelines and petrochemical components manufacturers are finally ready to shift to fully composite structures (Jha, 2013). The main issue is that estimated useful working life for those components to be economically viable should be in the order of the tens of years, possibly without any major maintenance.

To introduce a new material grade in a commercial product, such as a flexible riser pipeline, it has to be fully qualified first. The testing operations cannot be carried out at real timescale, as the technology would be obsolete by the time the product is ready to be introduced to the market. Therefore, there is a call for reliable accelerated testing methodologies, which shorten test times to reasonable levels, in order to successfully predict the evolution of the material properties over few decades.

A comparative accelerated testing methodology has been put to test. Neat thermoset epoxy and GFRP coupons of different shapes (from 19×19×2 up to 100×100×2 mm, to assess any possible scale effect) have been exposed in a simulated working environment, being soaked in

synthetic seawater at different exposure temperatures (25, 55 and 80 °C). The evolution of the material properties was monitored by different techniques. Standard gravimetric testing (ASTM D5229M) allowed the evaluation of fluid absorption progress. In parallel, the shift in the *glass transition temperature* (T_g) was monitored through an extensive campaign of Dynamic Mechanical Analysis (DMA) on fluid exposed and re-dried samples. The mechanical properties of the material were evaluated by quasi-static tensile testing (ASTM D638 & D3039M) of exposed specimens at selected intervals (at linear Fickian diffusion, saturation and after three more months of ageing). Samples exposed in dry air have also been tested in order to check the effect of the temperature alone.

RESULTS AND CONCLUSIONS

The results obtained show that there is a similar pattern in the properties change, which are shifted in time: the higher the temperature, the quicker the absorption process (see Figures 1 and 2). It suggests that this innovative approach could be a feasible way to accelerate the fluid diffusion and ageing phenomena occurring in the material over very long time exposure. Attention must be paid to possible secondary ageing mechanisms triggered by the higher temperatures, which would not occur at the typical operating scenarios.

Further work is needed on extending the DMA and mechanical testing. Newer and more computationally demanding diffusion kinetics (Grace, 2012) will be applied on the gravimetric data to achieve better accuracy in the description of the fluid diffusion mechanism and gain further prediction ability towards later ageing stage.

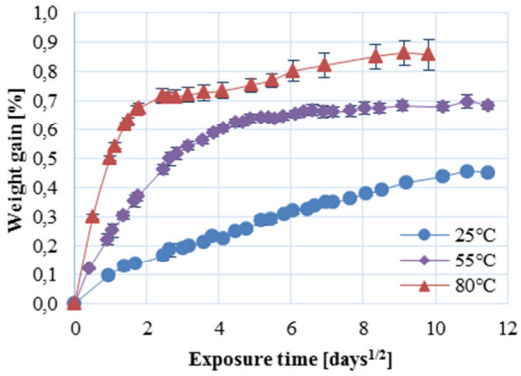

Fig. 1 - Gravimetric test results on seawater exposed composite coupons.

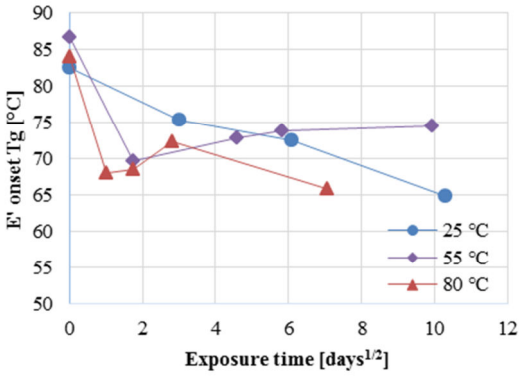

Fig. 2 - T_g shift evaluated by 3-point bending

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding from the EU Horizon 2020 Research and Innovation programme under the Marie Sklodowska-Curie grant agreement No 642557.

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