Retention of Mechanical Properties After Water Immersion for Glass-Fibre Polymer Composite Laminates with Thermoset & Thermoplastic Infusible Resins

Glass-fibre reinforced polymer (GRP) composite materials are the most widely adopted amongst fibre-reinforced polymer composites globally, with approximately 1 million tons produced annually in the EU alone. GRP's find very wide use and application in a number of industrial sectors (e.g. land & waterborne transport[1], marine, construction) due to their excellent balance between good performance and low cost compared to fibre reinforced polymers utilising other commercially available fibres (e.g. carbon, aramid).

Particularly in marine applications, durability of composites and their ability to exhibit unchanged performance and stability in a marine context and environment is a crucial factor in order to select the most appropriate combination of polymer matrix and reinforcement. Ideally, a composite would retain its mechanical and thermo-mechanical profile even when exposed to a marine environment for extended periods.

In this work, we conducted an extensive comparative study of the water absorption behavior and retention of mechanical properties of a group of GRP composite laminates manufactured with a range of infusible thermosetting and thermoplastics resins. Sample preparation for water immersion studies was according to ASTM D5229. This study was part of a comprehensive down-selection of commercially available resins in terms of their suitability for shipbuilding applications, as part of the EU H2020 project FIBRESHIP[2].

All laminates were manufactured by Vacuum-Assisted Resin Transfer Moulding (VARTM; the most relevant manufacturing technique in shipbuilding) with a range of state-of-the-art thermosetting resins (Urethane acrylate Crestapol 1210, Epoxy SR1125, Bio-epoxy Supersap CLR, Phenolic Cellobond J2027X) and a novel infusible acrylic thermoplastic resin (Acrylic Elium 150). The reinforcement of choice for each laminate was a unidirectional glass fabric of 996 gsm.

A selection of relevant properties of the laminates with different resin systems is presented in this paper including fibre volume fraction, apparent interlaminar shear strength (dry and wet condition), flexural strength (dry and wet condition) and flexural modulus (dry and wet condition). For the wet condition, samples were immersed in distilled water for 28 days at 35 ^{o}C (wet state) in accordance with classification society guidelines.

The quality of the laminates (void content, fibre-matrix adhesion) was examined by scanning electron microscopy on fracture surfaces. The effects of water absorption on the microstructure, mechanical, thermal & thermomechanical properties of the laminates were studied.

The average water absorption percentage varied across all resins systems from 0.19 to 1.37% in the interlaminar-shear specimens, and from 0.25 to 1.59% in the flexure specimens. The phenolic laminate was the one absorbing most water in both cases but the mechanical properties were relatively unaffected. Fibre volume fraction was in the range 0.56 to 0.6 for all of the laminates.

The majority of the tested GRP laminates showed good retention of their flexural properties and interlaminar shear strength under the testing conditions. The laminate that appeared to be most adversely affected was the infusible thermoplastic, showing a reduction in flexural strength and

interlaminar shear strength of 17.3% and 37.5%, respectively (in comparison to the dry state values). However, the water absorption for the Elium 150 was not excessive, ranging from 0.40 to 0.42% for the ILSS and flexure samples, respectively.

References:

[1] Summerscales J, Marine applications of advanced fibre reinforced composites, Woodhead Publishing, Cambridge, 2016

[2] H2020 project FIBRESHIP, funded by the European Commission under GA 723360 (www.fibreship.eu)