10th International Conference on Composite Science and Technology
ICCST/10
A. L. Araújo, J. R. Correia, C. M. Mota Soares, et al. (Editors)
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Abstract ID-208

THE LONG-TERM EFFECTS OF WATER ABSORPTION, DESORPTION AND RE-ABSORPTION IN CARBON-FIBRE / EPOXY COMPOSITES

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Keywords: water absorption, polymer composites, glass transition temperature, Fickian behaviour

Summary: Water absorption and desorption in polymer composites is important for long term performance, especially in outdoor applications. The epoxy and BMI resins used in many composites absorb water which leads to resin softening, swelling and loss of mechanical performance. At longer times and higher temperatures absorbed moisture can induce degradation in the polymer. To predict this effect, better understanding of the absorption behaviour of water is needed, especially over long times. It is well established for these resin systems that there is a continued slow increase in water content with time, beyond the initial Fickian behaviour. Various mechanisms for this have been proposed including molecular relaxation, chemical degradation and a Langmuir diffusion mechanism. This paper presents new information on this area for carbon-fibre / epoxy composites utilising some test samples that had been previously conditioned for long times (up to five years) in water and humid environments.

Long term water absorption, desorption and re-absorption tests have been carried out in a unidirectional and ±45° carbon-fibre reinforced epoxy composites. Samples have been previously conditioned in water at a temperature of 70°C for a period of five years and then dried at the same temperature. The slow continued increase in water content was evident over the whole time-range. Faster re-absorption was observed after drying with samples attaining equilibrium within a short time and showing a Fickian response. Dynamic mechanical tests were conducted to determine the effects of moisture on the glass transition temperature (Tg) and molecular relaxation of the material. Annealing was performed at 180°C to assess the influence of annealing on the effects of water absorption. Investigations revealed that the Tg values of the re-immersed samples were lower both in the UD and ±45° materials and a decrease in the height of the peak was seen when compared to the those subjected to absorption only. The Tg values correlated quite well with the water content, though for some long-term tests, a second relaxation peak developed as a result of molecular changes during conditioning. There was no significant change seen with annealing the samples after re-immersion and drying. FTIR spectroscopy and microscopy have shown that some chemical degradation and plasticizing effect caused depression in the glass transition temperature with a post peak plateau that appeared at about 180°C. From the results, it seems that both molecular relaxation and some chemical degradation at higher temperatures play a role and that the slow increase in water content continues for at least five years. There is a need for these to be included in any design analysis or modelling of the effects of water on long term composite performance.