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A Study on the Impact of Aerospace Fluids on the Durability of Fiber-Reinforced Composite Structures

C. Winkelmann, V. La Saponara
University of California, Davis, California, USA

Abstract

We present results of a multi-year investigation on the thermo-mechanical impact of fluids commonly used in aerospace operations, over the durability of epoxy-based structural adhesive (approved for maintenance and repairs) and woven carbon fiber-reinforced polymeric composites. These structural materials were individually immersed in water and undiluted/unmixed jet fuel, anti-icing jet fuel additive, hydraulic fluid. Gravimetric tests were carried out at three conditioning temperatures typical of those experienced by a composite aircraft structure in service: room temperature, 70 deg. C and 85 deg. C. The effect of post-curing of the structural adhesive was also studied. Hardness test data, statistical analysis and microscopy showed a significant loss of hardness for the structural adhesive samples treated in jet fuel additive or in hydraulic fluid, with irreversible phenomena that may be ascribed to diffusion-driven chemical reactions. The carbon/epoxy specimens experienced more limited damage, in particular due to jet fuel additive.

The moisture uptakes were modeled with two simple diffusion models used in the literature (Fickian, two-stage sorption or 'Langmuir'). Despite limitations inherent in these models, reasonably good fits were obtained, that captured the trends for adhesive and carbon/epoxy specimens immersed in water (as expected) or anti-icing additive (new result). On the other hand, the mass gain caused by hydraulic fluid could not be fitted by either model. The suitability of an Arrenhius trend is also assessed, since this is a common model in multiphysics software packages that may be used for this problem.

The results of this investigation appear to confirm the concerns of the US National Transportation Safety Board regarding hydraulic fluid exposure of aerospace composites (in fact, a warning was recently issued about delamination of the composite rudder of Airbus A300 aircraft due to hydraulic fluid leaks).