Thermal Aging of CFRP Composites for Marine and Aeronautical Applications

E. TROIANI*, L. DONATI, R. DI SANTE and P. PROLI

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Abstract

This paper provides an insight on the evolution of mechanical properties of CFRP materials for aeronautical and marine applications, when exposed to specific environmental conditions, i.e. cyclical variation of temperature. This study is carried out by means of the experimental characterization of static compression, three point bending and interlaminar shear, which generates results on fibers and matrix resistance and on the mechanical properties of the composite.

Because of their increasing use in aeronautical and marine applications, the polymeric matrix composites are often subjected to harsh environmental conditions, such as, for example, high and low temperatures, the action of chemicals and corrosive fluids, absorption of water and moisture, and exposure to UV rays. These actions can produce degradation, reducing the mechanical properties of the composites, and therefore the time of life of the product.

As a first approach, in the framework of Masterlab laboratory of the Bologna University, a study on the effect of thermal cycles (due to the day / night or at different altitudes difference of temperature) has been carried out through static characterization tests. A decay of the tensile strength is predictable, together with the creation of transverse and longitudinal cracks. This is due to the thermal stress endured, with the resulting loss of mass of the matrix, and to the different coefficients of thermal expansion (CTE) of fibers and matrix, which produce residual stresses, proportional to the CTE difference. The effects of decay mainly affect the polymer matrix, the weak element of the composite.

To investigate the behavior of a typical aeronautical CFRP material, the specimens were subject to cyclic thermal loads between 80 ° C and -20 ° C. The exposure time was 12 hours at both end temperatures, in order to reach thermal equilibrium.

Specimens were produced by means of autoclave processing at the Masterlab laboratory with stacking sequence of 12 plies $[0°]_{12}$ of plain weave fabric 200gr/sqm 3K impregnated by epoxy resin (GG205PIMP530R-43). Curing cycle was 1 hour at 130°C followed by 1 hour at 150°C all under 6,2 bar compactng pressure.

Department of Engineering for Industry (DIN), University of Bologna, 47121 Forlì, ITALY
*e-mail: enrico.troiani@unibo.it ; web page: http://www.masterlab.unibo.it

The behavior of the specimens was investigated by compression (ASTM D3410), three points flexural (UNI EN ISO 14125) and interlaminar shear (UNI EN ISO 14130) tests at different stages of thermal fatigue. The tests were performed after 1, 3, 6, 12, 24, 48, 66, 96, 126 and 132 cycles; for each condition and test method 5 specimens were characterized.
The test results show that the polymeric matrix is the element which undergoes the greater degradation, because it is the most exposed part of the composite and is particularly affected by the maximum temperature reached. This is reflected by the gradual lowering of the maximum shear stress, especially from the sixth cycle onwards. On the contrary, the fibers are almost not influenced by the cyclical variations of temperature. In fact, they are the strongest part of the composite and the most internal, so they are less exposed to radiation and climatic variarions. However, the residual stresses due to the sequence of expansions and contractions, slowly reduce the maximum stresses supported by the fibers.

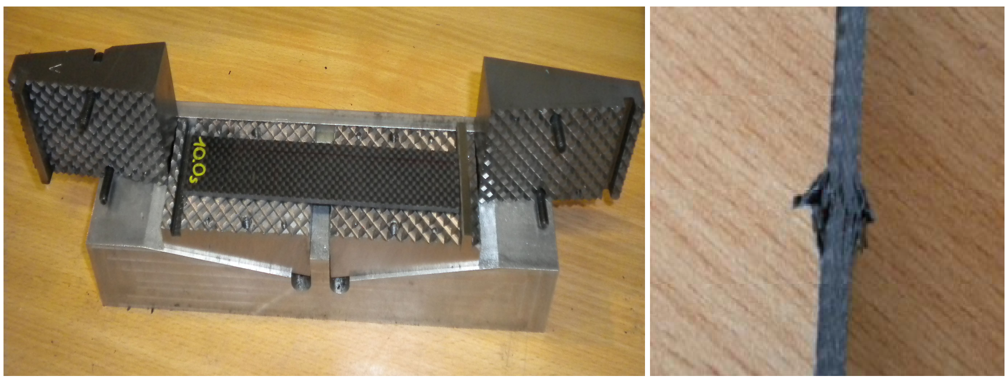

Figure 1. ASTM D3410 fixture and specimen.

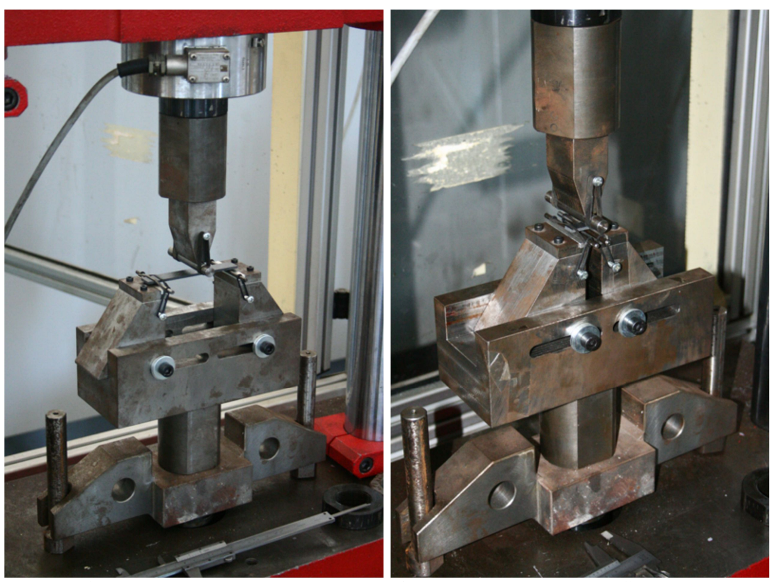

Figure 2. UNI ENISO 14125 and UNI EN ISO 14130 fixtures.