EFFECTS OF WATER AGING ON MECHANICAL PROPERTIES OF CONTINUOUS CARBON FIBER/POLYAMIDE 6 COMPOSITES

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Car designers are more and more in favor of using fiber reinforced green thermoplastic as growing environmental problems and a strict fuel efficiency mandate. Continuous carbon fiber reinforced polyamide 6 (PA6), which has been widely used in automobile for many years, is a good candidate to replace metal bearing structures to realize weight reduction. However, high water absorption due to high density of hydrogen bonds in PA6 make its properties to be discounted, which also should be concerned when matching with carbon fibers.

In this paper, carbon fiber of Zoltek Panex®35 reinforced UBE 1013B PA6 prepreg was firstly prepared through hot melt impregnation method and then unidirectional CF/PA6 laminates were manufactured by hot-pressing process. Molding time of 30s (C1), 150s (C2), and 600(C3) were respectively employed to control the different crystallinities of CF/PA6 composites. Laminates with water absorption were obtained by a harsh water aging method of immersing them in 90 ℃ water for 40 hours. Then four kinds of mechanical tests of 0 degree tensile, 90 degree tensile, three point bending and short beam shear were performed to evaluate the effect of water aging on CF/PA6 composite properties. SEM and POM were used to observe the variations of water aging on the failure cross sections and metallographic sections.

Results in Fig. 1 show that all strengths and moduli of four kinds of mechanical tests exhibit obvious declines after water aging except the modulus of 0 degree tensile. This is because matrix has limit contributions to the composite modulus in this direction. 90 degree tensile is the most sensitive test to the modulus variation of CF/PA6 composites, and 62~64 percent of modulus declines are shown for different crystalline composites after water aging. Bending test is more sensitive to the strength variations, and 53~61 percent of strength decreasing are obtained. Short beam shear is the only test that correctly reveals the crystallinity effects on CF/PA6 composite properties.

SEM results in Fig. 2 show that the strong matrix with big dimples are wholly replaced by a kind of weak plastic yielding matrix with long and thin polymer cross sections after water aging. In addition, fiber surface becomes smooth and interface debondings are clearly seen. These suggest that the crystalline structure of PA6 both inside the matrix and at the interface are destroyed and the polymers are all in a full amorphous state.

Metallographic microscopy results in Fig. 3 further reveal that the interface debonding has happened before mechanical test. Macroscopic cracks induced by propagating and coalescing of these interface debondings are also observed. More interestingly, they are more easily to be found in fiber rich areas. This is because interface is the weakest phase in CF/PA6 composites and they are more concentrated in these areas.

According to all the above results, we can conclude that water aging induced crystalline structure destruction of PA6, interface debonding, and macroscopic cracking together led to the final mechanical property declines of continuous CF/PA6 composites.

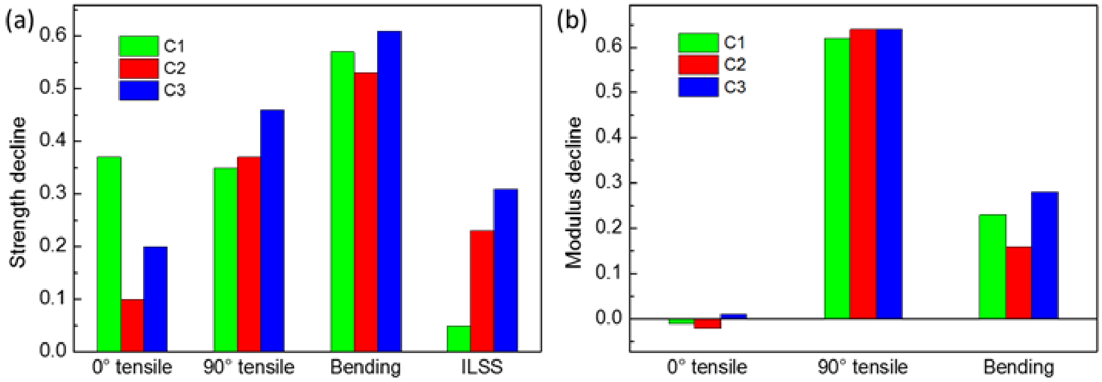

Fig. 1 Effects of water aging on four kinds of mechanical properties of CF/PA6 composites: (a) strength, (b) modulus

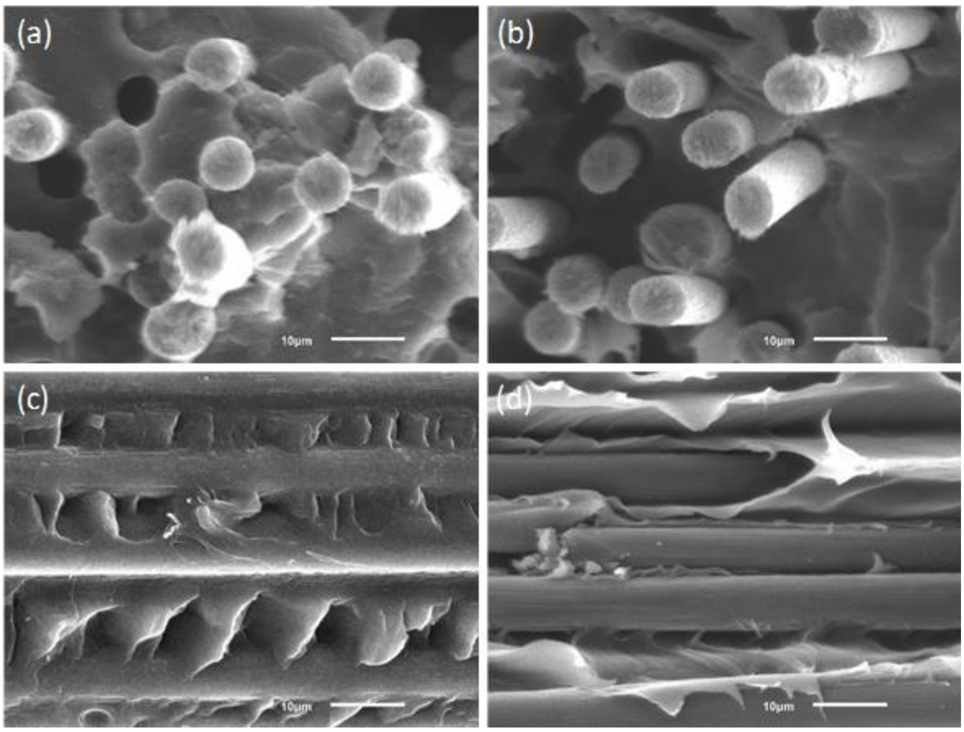

Fig. 2 SEM for the CF/PA6 composites failure cross sections: (a) 0 degree tensile before water aging, (b) 0 degree tensile after water aging, (c) 90 degree tensile before water aging, (d) 90 degree tensile after water aging

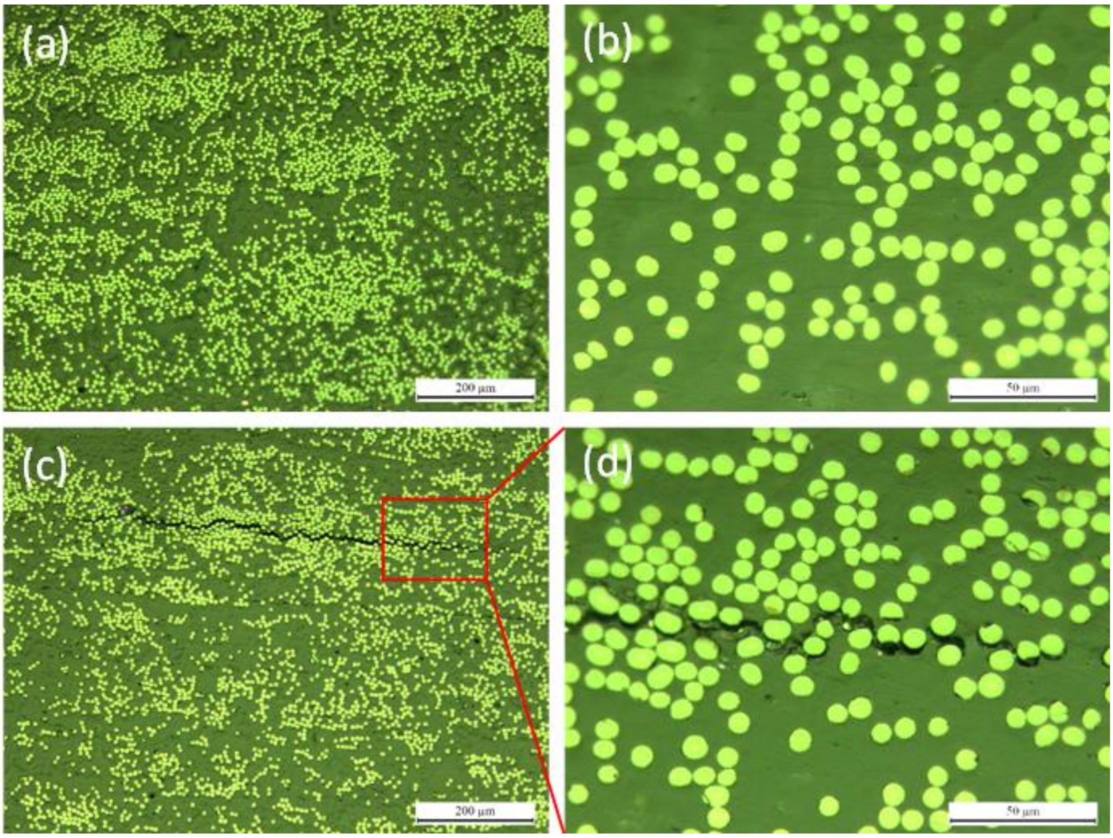

Fig. 3 Optical microscopy for the CF/PA6 laminate metallographic sections: (a) (b) before water aging, (c) (d) after water aging