HYGROTHERMAL AND ULTRAVIOLET (UV) RADIATION EFFECTS ON INTERLAMINAR SHEAR STRENGTH OF CARBON FIBER/PEKK COMPOSITES

Rogério Lago Mazur, rogermaz@uol.com.br
Murilo Bocatte Klen, mbklen@yahoo.com.br
Edson Cocchieri Botelho, ebotelho@feg.unesp.br
Department of Materials and Technology, UNESP, Guaratinguetá, São Paulo, Brazil.

Mirabel Cerqueira Rezende, mirabel@iae.cta.br
Divisão de Materiais, Instituto de Aeronáutica e Espaço, CTA, São José dos Campos, São Paulo, Brasil.

Abstract. *In the last years, advanced thermoplastic composites (ATC) have received much interest for high performance application. In the aeronautical sector, the composite used is susceptible to exposure to sunlight, variations in temperature and humidity and other conditions that may degrade the mechanical properties of the material. Moisture absorption by matrix has a plasticizer effect, with the glass transition temperature reduction and ultraviolet (UV) radiation can cause degradation by a process termed scission. These external factors normally have a great influence on the overall performance of these materials and can affect the interlaminar shear strength. Among the available thermoplastic composite, carbon fiber reinforced PEKK (polyether-ketone-ketone) composite shows excellent balance of properties, including higher glass transition temperature, high strength and stiffness, high toughness, low moisture absorption and excellent environmental resistance. The aim of the present work is to evaluate the influence of the hygrothermal and ultraviolet radiation effects on interlaminar shear strength of carbon fiber reinforced PEKK thermoplastic composites. The laminate was produced in UNESP/CTA with 12 plies of carbon fiber by using hot compression molding. The composites specimens were exposed to a combination of temperature (80°C) and humidity (90%) in an environmental conditioning chamber during two months and other set was exposed to repeated cycles of eight hours of UV radiation at 60°C and four hour of water condensation at 50°C during 1200hs. The interlaminar shear strength (ILSS) tests were carried out in appropriate device for shear test at Instron test machine.*

***Keywords**: Weathering, PEKK, carbon fiber, interlaminar shear test.*

1. INTRODUCTION

The combination of low density with high values of strength and rigidity allowed the advanced composites to be used in the aerospace industry, replacing the traditional metallic materials, allowing a reduction from 20 to 30% by weight and 25% of the cost in producing the final pieces [Rezende, Botelho, 2000; Costa, Rezende, Botelho, 2005].

The thermoplastic composites have some advantages over the conventional thermosetting used in aerospace, such as: not permanently harden and can be re-heated and formed several times, have good fatigue resistance, higher impact resistance, low moisture absorption, low cost of transport and storage, high temperature service and great versatility of mass production, showing mechanical properties equal or superior to those made by thermosetting composites [D'Almeida, De Almeida, De Lima, 2008; Phillips, Glauser, Manson, 1997].

The mechanical properties of polymer-matrix composites can be affected by environmental conditions. Composite materials are typically exposed to multiple environments during service, which leads to the possibility of synergistic degradation mechanisms. Excess of moisture can cause the absorption of water by the matrix, and consequently generate the plasticizer effect and reduced glass transition temperature, affecting the strength of adhesion between the fiber and matrix. Both, UV radiation and moisture have adverse effects on the mechanical properties of the polymeric matrix, while the carbon fibers are not affected significantly by either environment. The absorption of UV photons by polymers result in photo-oxidative reactions that after the chemical structure resulting in material deterioration [Ranby, Rabek, 1975]. These chemical reactions typically cause molecular chain scission and/or chain crosslinking or reticulation. Chain scission lowers the molecular weight of the polymer, giving rise to reduced strength and heat resistance. On the other hand, chain crosslinking and/or reticulated leads to excessive brittleness and can result in microcracking. However, for extended exposure to UV radiation, matrix dominated properties can suffer severe deterioration, e.g. interlaminar shear strength and flexural strength and flexural stiffness can all decrease (Hancox, Minty, 1977; Liau, Tseng, 1998; Shin, Kim, Hong, Lee, 2000). The fiber-dominated properties, such as tensile modulus and tensile strength, are usually not affected significantly, especially for carbon fiber-reinforced materials [Chin, Nguyen, Aouadi, 1997; Liau, Tseng, 1998].

Good fiber/matrix adhesion is necessary for the transfer of shear stress, can influence the stiffness, toughness and the failure behavior of the composite, especially under certain environmental conditions. In this case, the fiber/matrix interface has an important role in the performance of the laminate being considered as a third component of the composite [Nogueira, 2004; Burakowski, 2001; Cândido, Almeida, Rezende, 2000; Gao, Kim, 2001].

Laminated structures made of polymer composites, when used in service, may be requested by a number of mechanical loads. The main mechanical stresses assigned to various types of efforts that are working in the composite tension-compression and shear. The aim of the present work is to evaluate the influence of hygrothermal and ultraviolet (UV) radiation effects on interlaminar shear strength on carbon fiber reinforced PEKK thermoplastic composite.

2. EXPERIMENTAL

2.1. Material

Carbon fiber reinforced PEKK thermoplastic composite was produced by UNESP/CTA by using hot compression molding. During this process were used the appropriate thermal cycle obtained in previous work. As matrix was used PEKK and the reinforcement were used 12 plies of tensile carbon fiber.

2.1. Accelerated wethering test

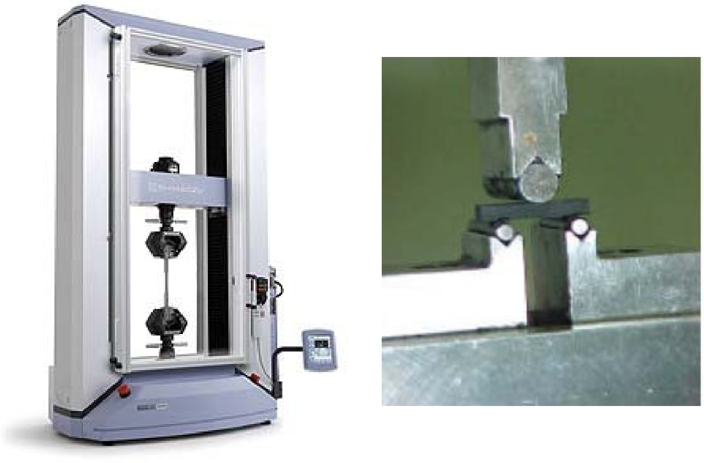
The accelerated weathering test has been done according to ASTM D 4587-05 and ASTM D 4329-05. The composites specimens were exposed to a repeated cycles of eight hours of UV radiation with a power of 0.76 W/(m^2.nm) at 60ºC and four hour of water condensation at 50ºC with UVB-313 type lamp. The specimens were removed after 1200h exposure of UV radiation exposed, in order to evaluate the stability of materials.

2.2. Environmental conditioning

In order to evaluate the influence of the hygrothermal effects on carbon fiber reinforced PEKK thermoplastic composites on interlaminar shear strength, the specimens were exposed to a combination of temperature and humidity in an environmental conditioning chamber. The conditions selected to saturate the specimens were based on procedure B of ASTM standard D 5229 M-92. The moisture level in the laminate was periodically monitored as a function of the time by measuring the mass of traveler samples until the moisture equilibrium state is reached. During conditioning, the temperature was set at 80°C and the relative humidity in the chamber was set to 90%.

2.3. Interlaminar shear strength

Carbon fiber reinforced PEKK thermoplastic composite was evaluated according to interlaminar shear strength – ILSS (ASTM-D2344). The specimens of 15 x 6,35 x 2,5mm (length x width x thickness) were tested in an universal Shimadzu machine using a test speed of 1.0mm/min, as shown in Figure 1.



(a) (b)

Figure 1. Interlaminar shear strength test of carbon fiber reinforced PEKK thermoplastic composite in a Shimadzu (a) and the adequate device used in ILSS (b).

2.4. Morphological analyses

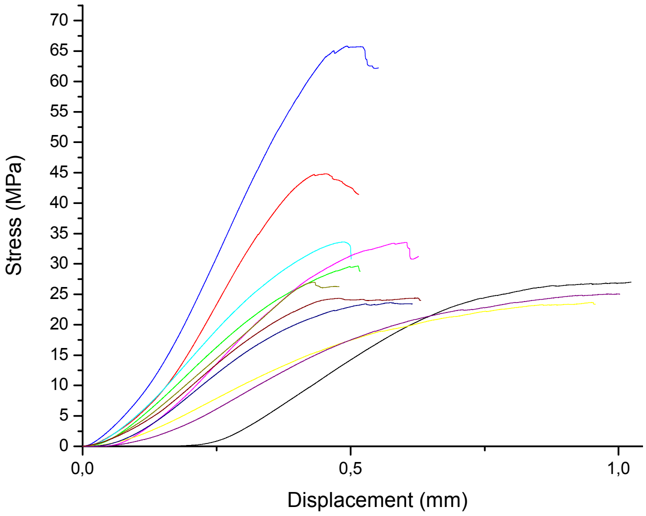
In order to evaluate the failure mode of carbon fiber reinforced PEKK thermoplastic composites by interlaminar shear strength, the specimens were analyzed by optical microscopy, as presented in Figure 2 (Epiphot 200).

Figure 2. Optical microscope used in this work.

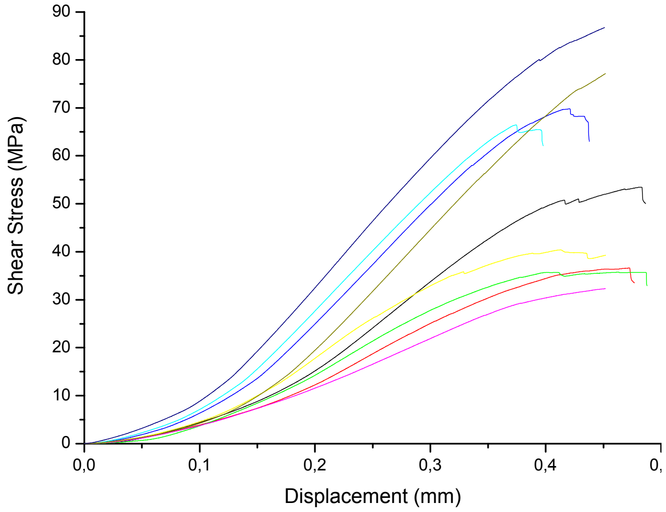
3. RESULTS AND DISCUSSION

In this work, it was observed that for all the composite specimens studied the moisture saturation point occurred after 50 days of exposure (with 0.20% of moisture).

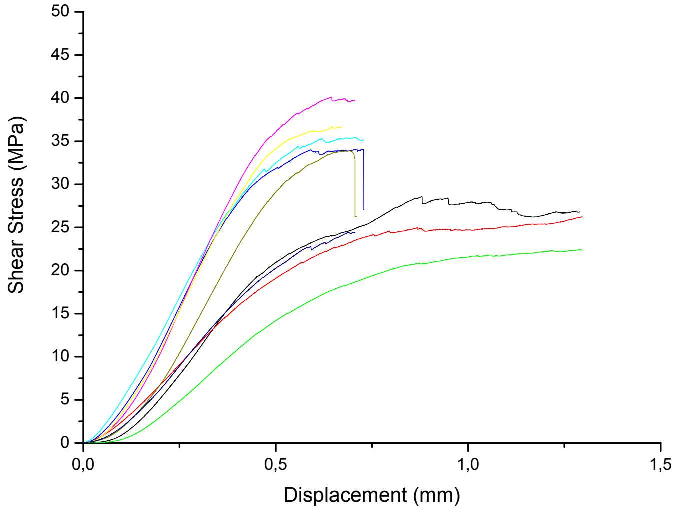
Figure 3 presents the curves of interlaminar shear stress versus displacement of carbon fiber reinforced PEKK thermoplastic composite of non-conditioned (dry), hygrohermal and UV radiation conditioned specimens. As can be observed in Figure 3 (a) and (c), respectively, the interlaminar shear strength of non-conditioned specimen (dry) and the specimens conditioned by UV radiation were approximately the same (around 32 MPa). This way, UV radiation no affected enough the thermoplastic specimens, no causing molecular chain scission (rupture of molecular chain bonds), showing a resistance extremely good an UV environmental conditions. However, the interlaminar shear strength of the specimen submitted to hydrothermal conditioning (Figure 3b), showed higher shear values, 62% higher when compared with non-conditioned specimen, in spite of reliable intervals have been superimposed for all of them. This behaviour probably can be relation with plasticization effects on polymeric matrix leading to an increase on mechanical properties of the laminate.



(a)



(b)



(c)

Figure 3. Shear stress versus displacement of carbon fiber reinforced PEKK thermoplastic composite: non-conditioning (a); hygrothermal conditioning (b) and UV radiation conditioning (c).

Figure 4 shows a cross section of non-conditioned carbon fiber reinforced PEKK thermoplastic composites, processed by hot compression molding, analyzed by optical microscopy. This figure shows a good infiltration of polymer into reinforcement produced thermoplastic composite with less voids and resin rich regions. During the consolidation of material, some variation in the symmetry of the press may have occurred, causing variations in the thickness of the laminate, and consequently hampering the distribution of reinforcement in the matrix. In this case, these regions induce less mechanical properties.

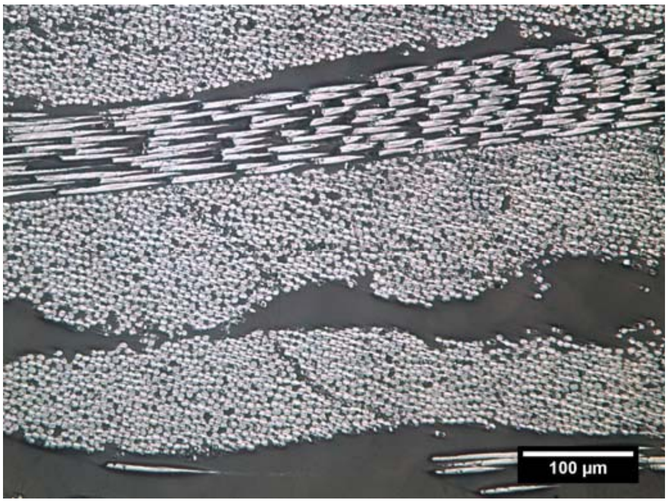
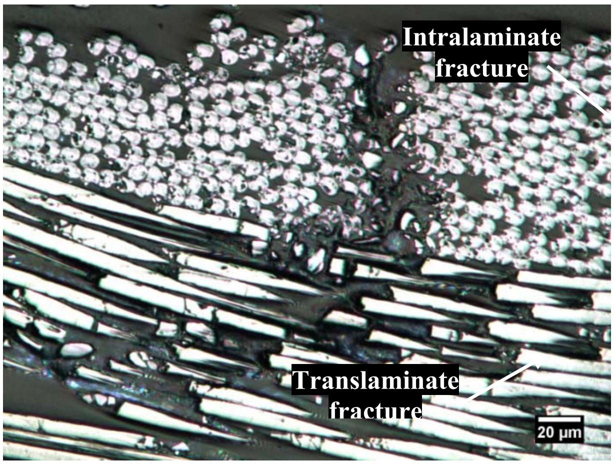


Figure 4. Morphological analyses of carbon fiber reinforced PEKK thermoplastic composite.

Figure 5 shows the representative optical microscopy of the non-conditioned PEKK/carbon fiber laminate after ILSS test. Basically, the morphology of the hygrothermal, UV and non-conditioned specimens were the same. As can be observed in these figures predominate the intralaminar and translaminar fracture.



(c)

Figure 6. Microscopy of the composite PEKK / carbon fiber after interlaminar shear test.

3. CONCLUSIONS

The influence of hygrothermal and UV light conditioning on shear properties of carbon fiber/PEKK laminates has been investigated. It was observed that this laminate absorbed 0.20% of moisture after the saturation point, when submitted to hygrothermal conditioning.

For all specimens studied in this work, the ILSS values increased when exposed to hygrothermal environmental conditioning. It is because the humidity induced matrix plasticization and, consequently, increase the shear strength values of the laminates. However, UV radiation was not affected enough causing molecular chain scission (rupture of molecular chain bonds), showing a resistance extremely good an environmental conditions.

In this work it was also observed that this laminate exhibit multiple delaminations having interlaminar and translaminar cracks at horizontal and vertical positions after and before to be submitted environmental conditionings. In this last conditioning, this behavior happened due probably to the higher ductility generate by the UV radiation process. Therefore, all specimens submitted to ILSS test exhibit the same failure modes.

3. ACKNOWLEDGEMENTS

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