EVALUATION OF VISCOELASTIC AND COMPRESSION PROPERTIES ON PPS/CARBON FIBER LAMINATES AFTER TO BE SUBMITED TO UV RADIATION

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Abstract: The purpose of this work is to evaluate the influence of the UV radiation on compression and viscoelastic properties of PPS/carbon fiber composites. This laminate has been supplied by Tencate Company. In this work, PPS/carbon fiber specimens were exposed to UV radiation during two different periods of time: 200 and 600 hours. After the weathering, compression tests and Dynamic Mechanical Thermal Analysis (DMTA) were performed. In this work, it was observed that no significant effect on compression test was observed but changes were observed during DMTA analyses when compared conditioned and non-conditioned specimens.

Key words: PPS/carbon fiber; thermal analyses; dynamic mechanical analyses.

1 INTRODUCTION

In recent years, have been observed an increasing interest in the use of fiber-reinforced polymer (FRP) composites in several fields such as: aerospace; aeronautical; automotive; marine; infrastructure; etc (Mohanty *et al*, 2001). Aeronautical polymeric composites are, in general, classified as advanced materials and present continuous fiber reinforcement of high-modulus or high-strength embedded in a thermoset or thermoplastic polymeric matrix. The appropriate performance of these composites during service is mainly related to their mechanical properties and thermal resistance as a result of the adequate combination of reinforcement, polymeric matrix and processing technique (Schwartz, 1997; Pitato and Michno, 1994).

Polymeric composites with carbon fiber reinforcements present similar or higher mechanical properties when compared with the conventional metallic materials due to its high strength-to-weight and stiffness-to-weight ratios. In addition, the polymeric composites present higher fatigue strength and higher corrosion resistance (Pitato and Michno, 1994; Baker *et al*, 2002).

Among the available thermoplastic matrices, the PPS (Polyphenylene Sulphide) are very used in aeronautical application. PPS is also very well-known polymer for its high service temperatures, low creep (even at elevated temperature), fairly low water absorption, quite high chemical resistance, high hardness, flame and thermal resistance, and high rigidity (Offringa, 1997; Mallick, 1993; Cebe, 1995; Chawla, 1987; Matthews and Rawlings, 1994; Fried, 2003).

However, during service, these composite materials are subjected to a variety of environmental conditions that are destructive, such as moisture, temperature cycling, and ultraviolet (UV) radiation. UV radiation, in particular, is known to be highly damaging to polymeric materials since the ultraviolet spectrum from the intensive sunlight may break the bond of the molecules, resulting in structural capacity degradations of the materials and the structures (Signor *et al*, 2003; Pang *et al*, 2001).

The main purpose of this study was to investigate the chemical and mechanical effects of UV radiation and moisture on carbon fiber/PPS laminates used in aeronautical applications. In order to accomplish this study, DMTA and compression tests were performed to evaluate the degradation after periods of 200 and 600 hours in an accelerated weathering chamber, with alternating cycles of UV radiation and humidity.

2 EXPERIMENTAL PROCEDURE

2.1. Materials

PPS 8-harness satin weave carbon fabric composite laminates, used in this study, were supplied by TenCate Advanced Composites, from Netherlands (5HS fabric style with 64% reinforcement volume content).

2.2. Accelerated weathering testing

Accelerated weathering testing was carried out using an accelerated weathering tester (Model QUV/spray with solar eye irradiance control) following the ASTM G154: Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Non-Metallic Materials using a fluorescent bulb UVB with 0.35 W/m^2 irradiance (at 340 nm), with cycles of UV irradiation for 8 h followed by 1 min spray of de-ionized water then 4 h condensation. The same PPS/carbon fiber laminates specimens to be used in mechanical tests were submitted to the aging process for durations of 200 and 600 h.

2.3. Dynamic Mechanical Thermal Analysis (DMTA)

Dynamic Mechanical Thermal Analysis was used to determine the glass transition temperature changes of the carbon fiber/PPS composite. The DMTA was performed at a fixed frequency of 1 Hz and a maximum displacement of 10 μm, the temperature used was varied from 20 to 250°C at a rate of 3°C/min. Four specimens for each situation were used in the DMTA with dimensions of 60 x 10 x 2 mm. These tests were performed on a Thermal Analysis Instruments 2980 DMTA that employs a cantilever bending geometry to displace the specimen.

2.4. Compression test

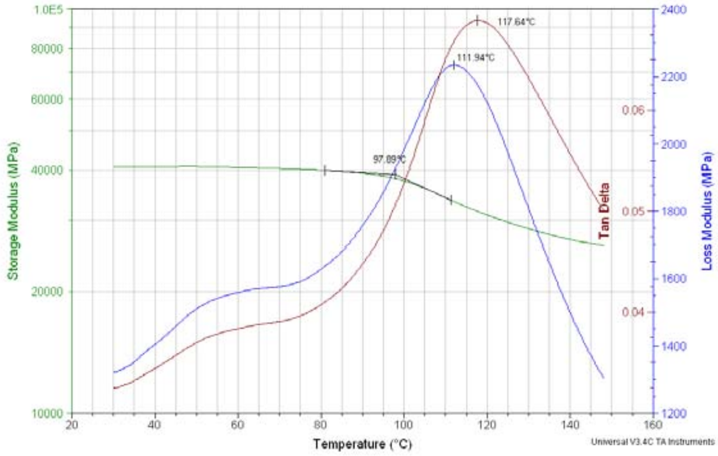
The compression test was carried out according to ASTM D3410, using five specimens with the dimensions of 100 mm of length, 12.3-12.7 mm of width and 1.6-1.9 mm of thickness, for each different exposition period. The specimens were prepared by bonding end-tabs of glass fibers/epoxy laminate. These tests were performed on a Shimadzu Precision Universal Tester (Autograph AG-X Series), at constant cross-speed of 1.27 mm/min, at room temperature.

3 RESULTS AND DISCUSSION

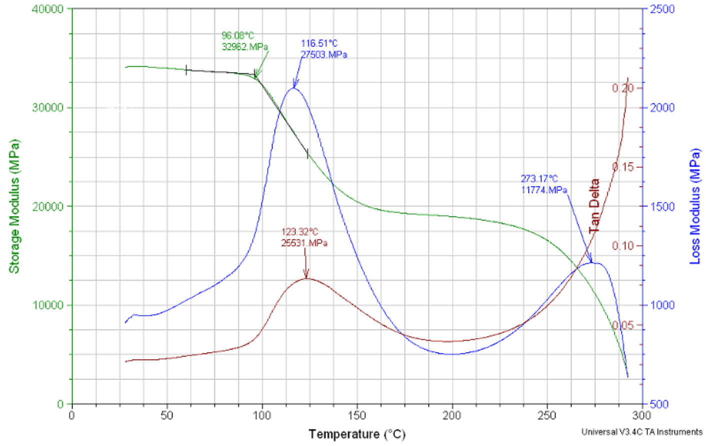
3.1 Dynamic Mechanical Thermal Analysis (DMTA)

In this work, DMTA investigation have been performed in order to evaluate the differences between the viscoelastic behavior of carbon fiber/PPS specimens after and before the UV weathering for periods of 200 and 600 hours. Representative DMTA results are shown in Figures 1a-c, respectively. Table 1, summarize the glass transition temperature for this three different conditions.

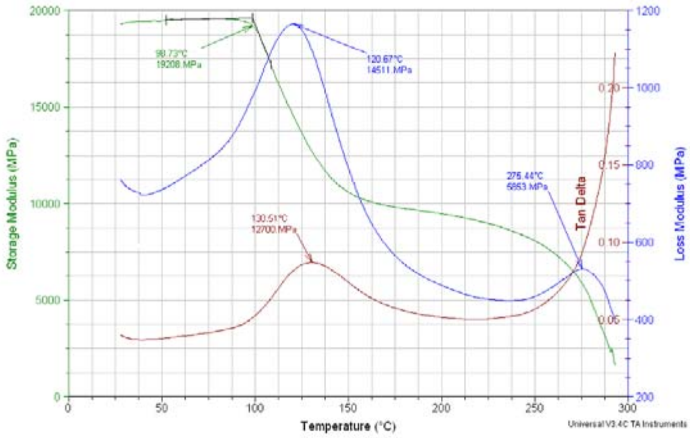
Table 1 shows a slight increase in the glass transition temperature as the period of weathering increases, considering the standard deviation. These changes in the Tg, imply a decreased material mobility, probably due to a process of reticulation with the laminates are submitted during the ultraviolet exposure. This behavior is associated with the plasticization mechanisms since can be also observed the decrease of the storage modulus when the graphics are analyzed between 30°C and 100°C with the UV exposition time. Similar works have been related by the literature (Signor *et al*, 2003; Pang *et al*, 2001). In order to confirm this explanation new experiments such as FT-IR and chromatography have been performed.



(a)



(b)



(c)

Figure 1: Dynamic Mechanical Thermal Analysis (DMTA): a) Before UV weathering; b) After 200 hours of weathering; c)After 600 hours weathering.

Table 1: Glass transition results.

Glass transition temperature	before UV weathering	after 200 hours of weathering	after 600 hours of weathering
Tg (°C)	111.94 ± 1.22	116.51 ± 2.10	120.62 ± 1.42

3.2 Compressive strength

Ultraviolet radiation in presence of oxygen can cause simultaneous reticulation and degradation reactions. The degradation process is also called photo-oxidation, which causes oxidation of the polymer surface in the presence of oxygen that is facilitated by UV radiant energy. This photo-oxidation includes chain scission, crosslinking and oxidative reactions. Compressive strength value for each group of laminate is given in Table 2. The results indicate that after the UV weathering the strength value increase until 8%. These results are due probably to the reticulation process generate by the ultraviolet radiation.

After the first 200 hours of UV exposure, the reticulation process improved the compression strength of the laminate, however, when the period of exposure was extended to 600 hours, the strength values decreased. This probably occurs due to intensification of the degradation process or even excess of reticulation. Similar works have been related by the literature (Signor *et al*, 2003; Pang *et al*, 2001).

This decrease also indicates that the molecular weight of the PPS matrix was reduced due to chain-scission reactions induced by photo-oxidation from UV radiation. The small amount of the actual decrease in the values found by 600 hours of weathering is due to the fact that changes induced by UV radiation are surface phenomena.

Table 2: Compression strength values.

	before UV weathering	after 200 hours of weathering	after 600 hours of weathering
Strength (MPa)	358.7±20.2	388.7±31.0	371.5±20.3

4 CONCLUSIONS

The effects of environmental degradation on mechanical properties were established by conducting a series of DMTA and compression tests. A possible reticulation process associated with plasticization phenomena has been observed on PPS/carbon fiber laminates after ultraviolet exposition, leading to an increase on the Tg for both cases (200 and 600 h) and a gain of compressive strength after this conditioning. This compression gain decay for the 600 h of UV exposure, with the probable combination action of reticulation and degradation. Therefore, in long periods of environmental exposure, the synergism between UV and condensation will cause so much damage that load transfer between fibers will longer possible owing to matrix erosion. This would then lead to deterioration of even fiber-dominated properties and could even results in catastrophic structural failure.

5 ACKNOWLEDGEMENTS

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