WEATHERING EFFECT ON DYNAMIC MECHANICAL THERMAL BEHAVIOR OF CARBON FIBER/PEKK COMPOSITES

Rogério Lago Mazur, rogermaz@uol.com.br
Department of Materials and Technology, UNESP, Guaratinguetá, São Paulo, Brazil.

Pedro Carlos de Oliveira, oliver@dequi.eel.usp.br
Faculdade de Engenharia Química de Lorena, USP, Lorena, São Paulo, Brazil.

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, Brazil.

Abstract. *The aim of the present work is to evaluate the influence of weathering effect (UV radiation) on carbon fiber reinforced PEKK thermoplastic composites by dynamical mechanical thermal analysis. In this work can be observed that the specimens submitted to the weathering effects test presented similar glass transition temperature when compared to the non-conditioned and conditioned specimens, showing a good thermal stability and, for both conditions, the storage modulus showed a stead behavior until 200 hours of UV radiation exposition. After this period, the composite specimens showed a worst behavior being observed that the storage modulus for conditioning specimens at 600, 1200 and 2400 exposition hours, were 26, 49 and 71% lower, respectively, when compared with non-conditioned specimens. This behavior shows a relation with degradation process, consequently, some mechanical properties, such as storage modulus of polymeric composite may be affected.*

Keywords*: Weathering, PEKK, carbon fiber, DMTA.*

1. INTRODUCTION

Advanced thermoplastic composites (ATC) have been lately introduced as structural composites materials for high performance aerospace applications over the last 40 years (Kaw, 1997). Among the thermoplastic composites, carbon fiber reinforced PEKK thermoplastic composites has shown excellent balance of properties, including higher glass transition temperature, high strength and stiffness, high toughness, low moisture absorption and good environmental resistance when compared to the conventional structural laminates (Mazur *et al*., 2008).

Advanced polymeric materials can present problems when exposed to moisture, temperature, ultraviolet radiation (UV), thermal cycling and mechanical fatigue, and may be affected by synergistic degradation mechanism, causing millions of dollars of material damage ever year (Kumar *et al*., 2002).

The greatest damage to polymeric materials exposed to environmental conditions is caused by the UV portion of sunlight, even though this portion represents up to 10% of the total energy reaching the earth from the sun, with about 50% of it being visible light and about 40% IR light (Tarantili, Kiose, 2008). The UV radiation absorbed by polymers result in photo-oxidative reactions that alter the chemical structure causing molecular chain scission and/or chain crosslinking. Chain scission lowers the molecular weight of the polymer, giving rise to reduce strength and heat resistance. On the other hand, chain crosslinking leads to excessive brittleness and can result in microcraking (Kumar, *et al*., 2002).

The presence of moisture within polymeric composites can lead to significant change of the chemical and physical characteristics of the polymer matrix and can undergo plasticization (Costa, *et al*., 2005). When UV radiation and moisture act in conjunction, the matrix dominated properties can suffer severe deterioration, and shows a reduction in glass transition temperature (T_g) and some mechanical properties, such as young's modulus of polymeric composites (Callister, 2000; Kumar, *et al*., 2002; Mazur *et al*., 2008a; Nakamura, 2002).

The weathering effect in polymeric composite is of great importance for developing materials more resistant than those available in the past and for forecasting the limit of their use (Tarantili, Kiose, 2008). The aim of the present work is to evaluate the influence of weathering effect on carbon fiber reinforced PEKK thermoplastic composites by using dynamic mechanical thermal analysis.

2. EXPERIMENTAL

2.1. Materials

Five specimens of dimensions of 55mm x 13mm x 2,5mm of carbon fiber reinforced PEKK (polyether ketone ketone) thermoplastic composite was produced by UNESP/CTA by using hot compression molding technique. As reinforcement were used 12 plies of carbon fiber. During this process were used the appropriate thermal cycle obtained by Mazur *et al*. (2008).

2.2. Accelerated weathering 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 at 200, 600, 1200 and 2400 hours exposure to produce defined change in material property in order to evaluate the stability of materials.

2.3. Dynamic mechanical thermal analysis

The dynamic mechanical thermal behavior of specimen was evaluated by a Thermal Analyzer TA Instruments, operating in three-point bending horizontal measuring system. The experimental conditions used were: dynamic force (0,7Nm); oscillation displacement (10μm); 1,0 Hz frequency, heating rate (3,0ºC/min) and temperature range of 30-250°C.

3. RESULTS AND DISCUSSION

Figures 1 to 5 show the curves of dynamic mechanical thermal analysis as function of temperature of specimens of carbon fiber reinforced PEKK thermoplastic composite (non-conditioned and conditioned in UV accelerated weathering tests) studied. In this work it was used the loss modulus peak (E") in order to evaluate the glass transition temperature (T_g). As can be observed in Fig.1 the non-conditioned specimen presented a glass transition temperature (T_g) of 162ºC and a storage modulus of approximately 35GPa until the temperature of 153°C.

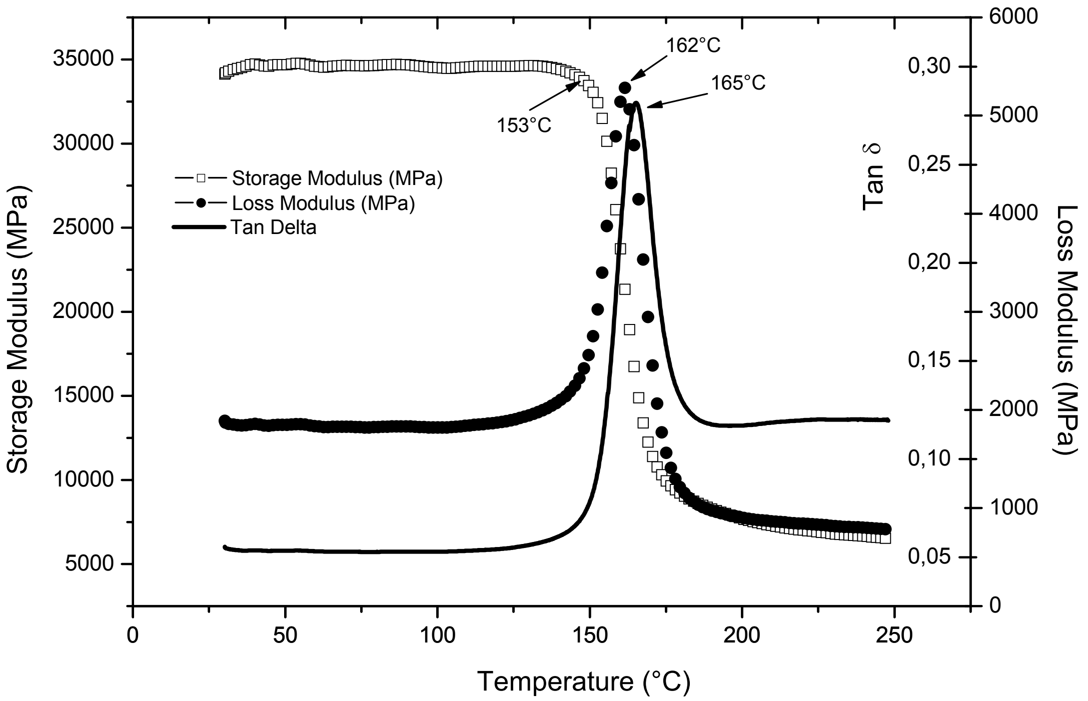

Figure 1. Dynamic mechanical thermal analysis of carbon fiber reinforced PEKK thermoplastic composite non-conditioning.

Figures 2, 3, 4 and 5 show the curves of dynamic mechanical thermal analysis as function of temperature of carbon fiber reinforced PEKK thermoplastic composite specimens after the accelerated weathering tests conditioning until 200, 600, 1200 and 2400h, respectively. All these Figures presented a similar behavior and as can be observed the conditioned specimens until 200, 600, 1200 and 2400h presented a glass transition temperature (T_g) of 157ºC, 160°C, 162°C and 162°C, and a storage modulus of approximately 37GPa, 26GPa, 18GPa and 10 GPa until the temperature of 110°C, respectively.

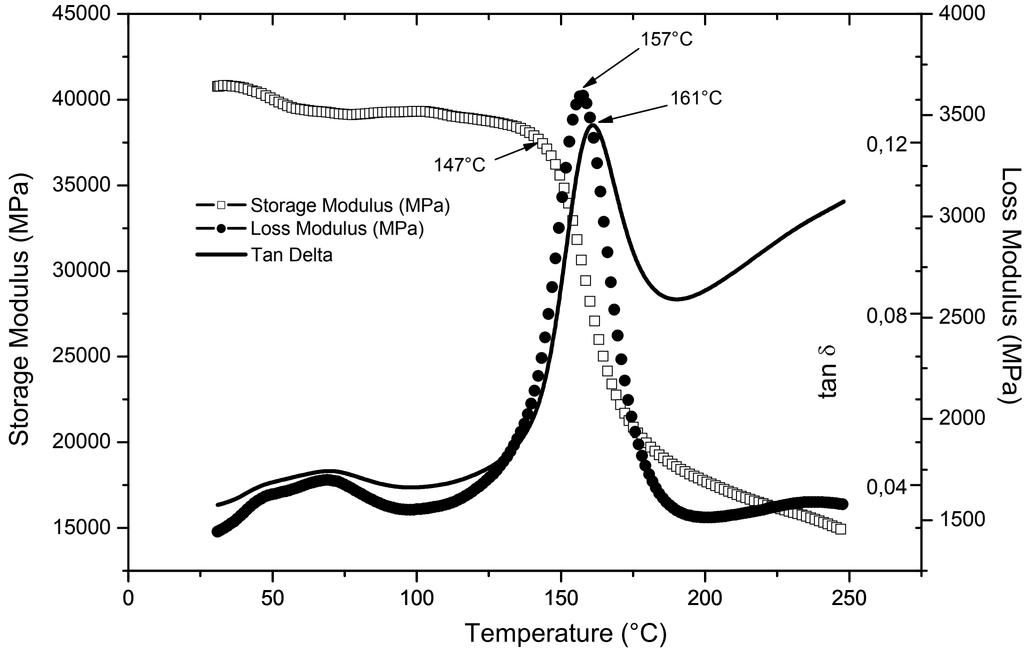

Figure 2. Dynamical mechanical thermal analysis of carbon fiber reinforced PEKK thermoplastic composite conditioned until 200h.

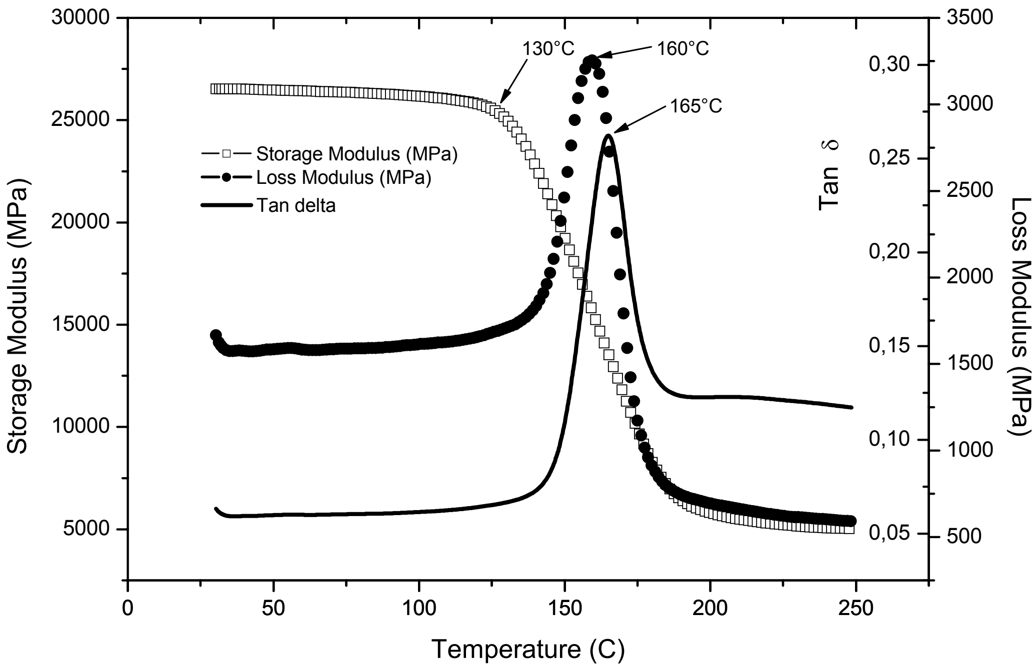

Figure 3. Dynamic mechanical thermal analysis of carbon fiber reinforced PEKK thermoplastic composite after the UV conditioning until 600h.

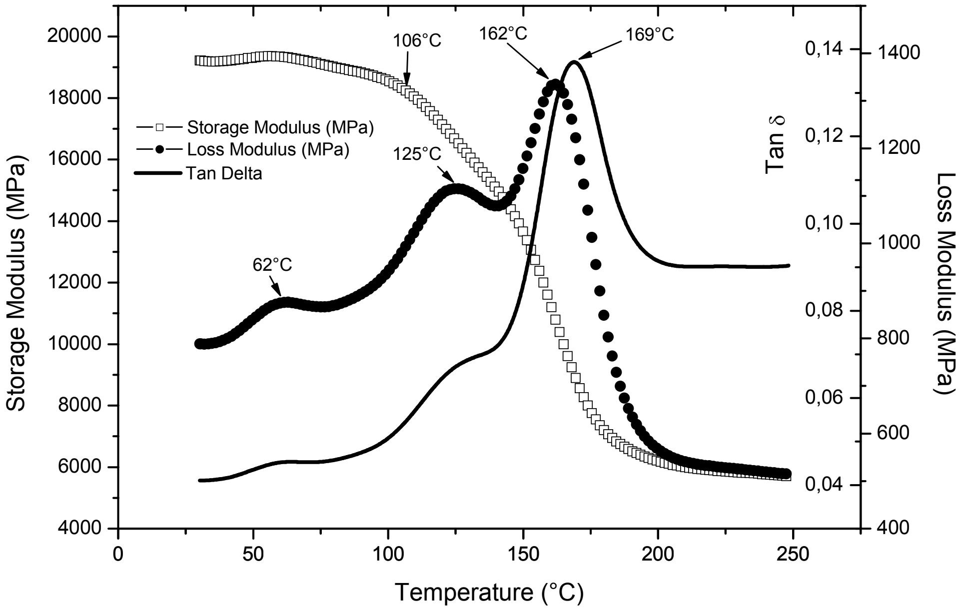

Figure 4. Dynamic mechanical thermal analysis of carbon fiber reinforced PEKK thermoplastic composite conditioned until 1200h.

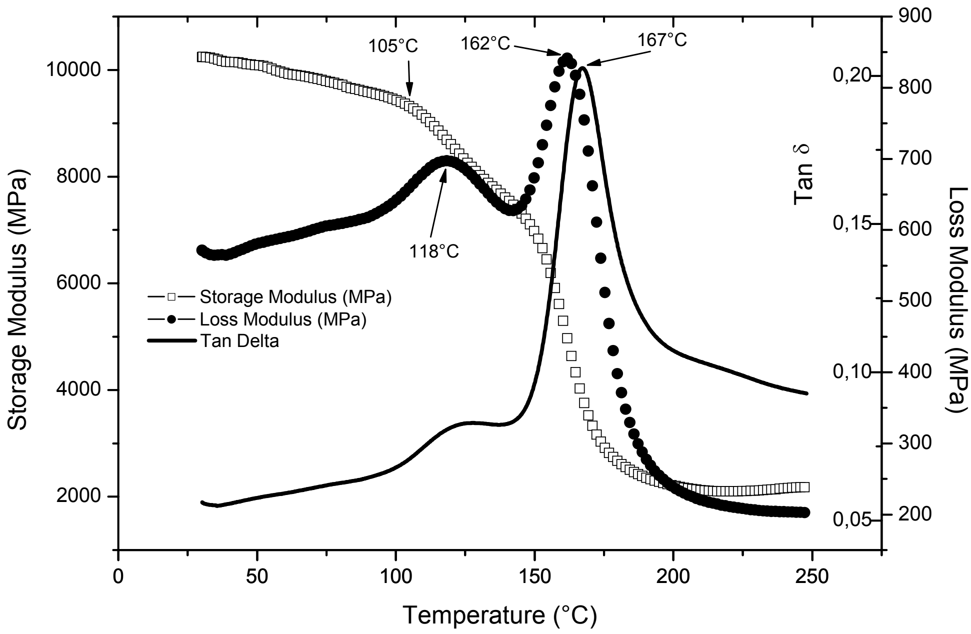

Figure 5. Dynamic mechanical thermal analysis of carbon fiber reinforced PEKK thermoplastic composite conditioned until 2400h.

Table 1 summarize the results obtained by the dynamic mechanical thermal analysis as function of temperature of carbon fiber reinforced PEKK thermoplastic composite specimens (non-conditioned and conditioned (200-2400 h) in accelerated weathering tests). As can be observed, the glass transition temperature (T_g) of the non-conditioned and conditioned specimens occurs in a similar temperature (~157 to 162°C), showing that the UV radiation used was not enough to promote substantial changes on the chairs mobility, however, the storage modulus showed a significant variation after 200h of UV conditioning exposition. In this work it was observed that the storage modulus results for the conditioned specimens until 600, 1200 and 2400 hours were 26, 49 and 71% lower, respectively, when compared with non-conditioned specimens. This behavior shows a relation with the degradation process (rupture of molecular chain bonds) associated with reticulation process. When UV radiation and moisture (plasticization) act in conjunction, the matrix-dominated properties can suffer severe deterioration, consequently, some mechanical properties, such as storage modulus of polymeric composite may be affected. Associated with this fact, it can be expected that over 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.

Table 1. Results of dynamic mechanical thermal analysis as function of temperature of carbon fiber reinforced PEKK thermoplastic composite specimens (non-conditioned and conditioned specimens).

Specimens (PEKK)	1	2	3	4	5
Exposed time (h)	Non-conditioning	200	600	1200	2400
Glass transition – T_g (°C)	162	157	160	162	162
Storage Modulus - E' (GPa)	35	37	26	18	10
Loss Modulus - E" (GPa)	5.25	3.60	3.25	1.30	0.85
Tan (δ)	0.28	0.13	0.26	0.14	0.20

3. CONCLUSIONS

In this work can be concluded that the specimens submitted to the weathering effects test presented a glass transition temperature similar to the conditioned specimens (values from ~157 to 162°C), showing a good stability; however, the storage modulus showed a stead state behavior only until 200 hours (~35 to 37GPa). After this period, the specimens of composites showed a worst mechanical behavior. This behavior shows a degradation process associated with reticulation mechanisms by a process termed scission (rupture of molecular chain bonds), consequently, some mechanical properties, such as storage modulus of polymeric composite may be affected.

3. ACKNOWLEDGEMENTS

The authors acknowledge the CAPES and FAPESP under grant 05/54358-7 and 08/00171-1 for the financial support.

4. REFERENCES

Costa, M.L., Almeida S.F.M., Rezende M.R.; 2005, "Hygrothermal Effects on Dynamic Analysis and Fracture Behavior of Polymeric Compoites", Materials Research, Vol.8, n°3, pp.335-340.

Callister, W.D.Jr., 2000, "Materials Science and Engineering an Introduction", John Wiley & Sons, ed. 5th, pp. 1-871.

Kaw, A.K., 1997, "Mechanics of Composites Materials", CRC Press LLC, Boca Raton, Florida 3343, pp1-323.

Kumar, B.G.; Sing, R.P.; Nakamura T., 2002; "Degradation of Carbon Fiber – Reinforced Epoxy Composites by Ultraviolet Radiation and Condensation", Journal of Composites Materials, Vol.36, pp.2713-2733.

Mazur, R.L.; Costa, M.L.; Botelho, E.C.; Rezende, M.C.; 2008, "Avaliações Térmicas e Reológica da Matriz Termoplástica PEKK utilizada em compositos aeronáuticos", Polimeros Ciencia e Tecnologia, Vol.18, pp. 237-243.

Mazur, R.L.; Costa, M.L.; Botelho, E.C.; Rezende, M.C.; 2008, "Hygrothermal Effects on Viscoelastic Behavior of Carbon fiber Reinforced PEKK Thermoplastic Composites", 13th European Conference on Composites Materials", Estocolmo.

Tarantili, P.A.; Kiose,V.; 2008, "Effect of Accelerated Aging on the Structure and Properties of Monolayer and Multilayer Packaging Films", Journal of Applied Polymer Science, Vol.109, pp. 674-682.

5. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.