EXPERIMENTAL INVESTIGATION OF PHYSICAL AGING EFFECT ON THE MECHANICAL PROPERTIES OF A CARBON/POLYIMIDE BRAIDED COMPOSITE

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1 General Introduction

This work aimed at acquiring knowledge about the thermo-mechanical behavior of a braided composite material for elevated temperature service conditions. More specifically, static and aging properties were studied.
To this end, a setup and a procedure that allows for obtaining valuable data on the physical aging for both the polyimide matrix alone and the braided carbon-polyimide composite material was developed. This paper deals with the experimental aspect and raw results.

2 Experimental details

2.1 Background and objective

The material studied was an aerospace grade polyimide matrix and its braided fabric composite.

For the polymeric matrix, the main goal was to obtain experimental data from multiple aging tests at different temperatures and different stress levels for different aging times. To this end, a series of aging tests were performed on polyimide specimens following the procedure developed by Struik [1]. This method consists of sequential creep-recovery tests done for different aging times at a given aging temperature [1,2,3]. These tests were mainly isothermal short term (IST) aging tests, which means that creep duration was 10% or less of the previous aging time. Expected results are a stiffer and more brittle material and also a shift in the creep curves resulting from a change in the viscoelastic properties. Since this work was done in partnership with the aerospace industry, a first temperature level of Wet T_g-50°F was selected. It is the industry standard for the maximum temperature allowed for polymeric composite materials. Aging tests at this temperature were performed over a year. Other temperatures between Wet T_g-50°F and Dry T_g were also tested during shorter periods of time, for modeling purposes.
At the same time, composite specimens were aged at Wet T_g-50°F to measure the effect of the change in the matrix properties on the composite properties.
In addition, mass loss and volume contraction were monitored during the aging process for a complete behavior understanding and modeling possibilities.

2.4 Specimens

Polyimide specimen type was chosen according to ASTM D638 and ASTM D2990 standards for tensile testing and tensile creep testing of plastics. All creep-recovery tests were done on ASTM type I specimens for tests at Wet T_g-50°F. Composite tensile specimen type was chosen in compliance with ASTM D3039 standard.
For aging tests done at higher temperatures during shorter periods of time, flexural tests were used instead to reduce material cost. ASTM D790 and ASTM D2990 standards for flexural properties of unreinforced plastics and flexural creep of plastics were used.

2.3 Experimental setups

The experimental setup used for tensile testing featured a high temperature furnace. Mechanical loading was introduced by a MTS 810 mechanical testing machine. A high temperature extensometer was used to measure strain while thermocouples measure the temperature in the gage section. This setup can achieve less than 0.5% temperature dispersion across the gage section for very repetitive data quality.
An ASTM type IIA oven was used to age specimens over a year (temperature uniformity inside the oven

within 1% of differential between oven and ambient temperature). It complies with industry standards such as ASTM E145, UL746B and ASTM E3035 standard for heat aging of plastics without load.

For flexural tests an electromechanical testing system equipped with an environmental chamber was used. Aging tests were conducted on a custom made three-point bending system on matrix specimens only.

3 Results

Matrix specimens that were aged for a year at Wet Tg-50°F showed significant changes in their mechanical properties. Up to 5 months, the matrix exhibited expected stiffening and a change in viscoelastic properties [1,3]. Figure 1 shows a comparison between curves obtained after 3 hours and 3 weeks of aging for different specimens. Very consistent results were obtained.

Besides mechanical tests, the evolution of the mass on matrix and composite coupons, different from the tensile specimens, was observed. Results demonstrate that there is a mass loss during the aging process. An expected decrease in volume was also measured. These changes are noticeable on the aspect of composite specimens, as shown in Figure 2 where there is clearly less matrix on the surface of the aged composite. Despite this significant effect of aging on the matrix properties, no noteworthy changes were observed on the elastic properties of the composite. Upcoming failure tests on both aged matrix and composite will lead to a better understanding of the use of this polyimide matrix in composites for an extended period at Wet Tg-50°F (aerospace standard). Results have shown that physical aging is occurring at this temperature as well as thermal degradation. This can't be disregard when designing aerospace parts for an elevated temperature use. Testing procedures and results generated in this work can be exploited as a guideline when working with new composite materials for an elevated temperature application.

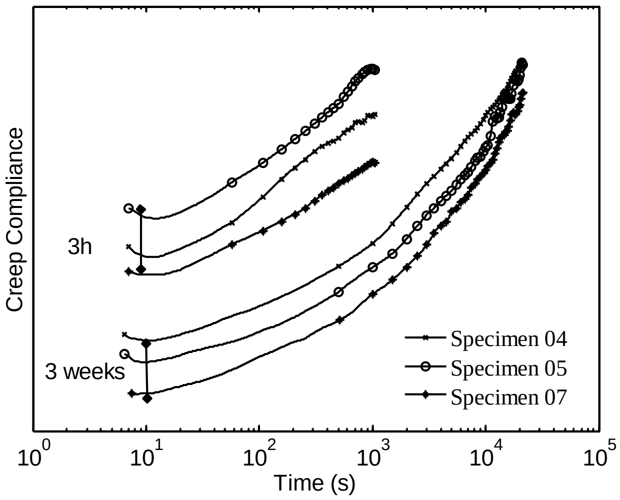

Fig.1. Creep compliance curves for specimens aged at Wet T_g-50°F.

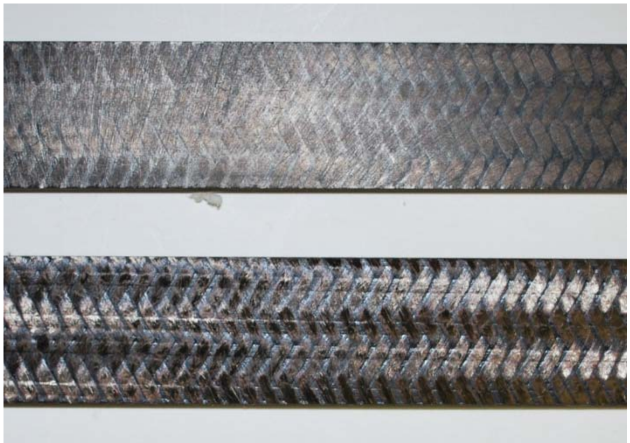

Fig.2. Comparison between non-aged composite (top) and composite aged for a year at Wet T_g-50°F.

References

[1] L. C. E. Struik "*Physical Aging in Amorphous Polymer and other Materials*". Elsevier Scientific, Publishing Company, 1978.

[2] R. D. Bradshaw and L.C. Brinson "A Continuous Test Data Method to Determine a Reference Curve and Shift Rate for Isothermal Physical Aging". *Polymer Engineering and Science*, Vol. 39, No. 2, pp 211-235, 1999.

[3] J. M. Hutchinson "Physical Aging of Polymers". *Progress in Polymer Science*, Vol. 20, pp 703-760, 1995.