Investigation of Hygro-Thermal Aging On Carbon/Epoxy Materials for Jet Engine Fan Sections

This poster summarizes 2 years of aging on E862 epoxy and E862 epoxy with triaxial braided T700s carbon fiber composite. Several test methods were used to characterize chemical, physical, and mechanical properties of both the resin and composite materials. The aging cycle that was used included varying temperature and humidity exposure. The goal was to evaluate the environmental effects on a potential jet engine fan section material. Some changes were noted in the resin which resulted in increased brittleness, though this did not significantly affect the tensile and impact test results. A potential decrease in compression strength requires additional investigation.

INVESTIGATION OF HYGRO-THERMAL AGING ON CARBON/EPOXY MATERIALS FOR JET ENGINE FAN SECTIONS

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Objectives:

Determine potential effects of aging on emerging composite engine structures

- Identify primary mechanisms that are active during the aging process for composite materials.
- Measure aging induced changes in the materials.
- Evaluate the potential effects of these changes on material performance.

Challenges:

Evaluate the effects of complex aging mechanisms in an engine service environment

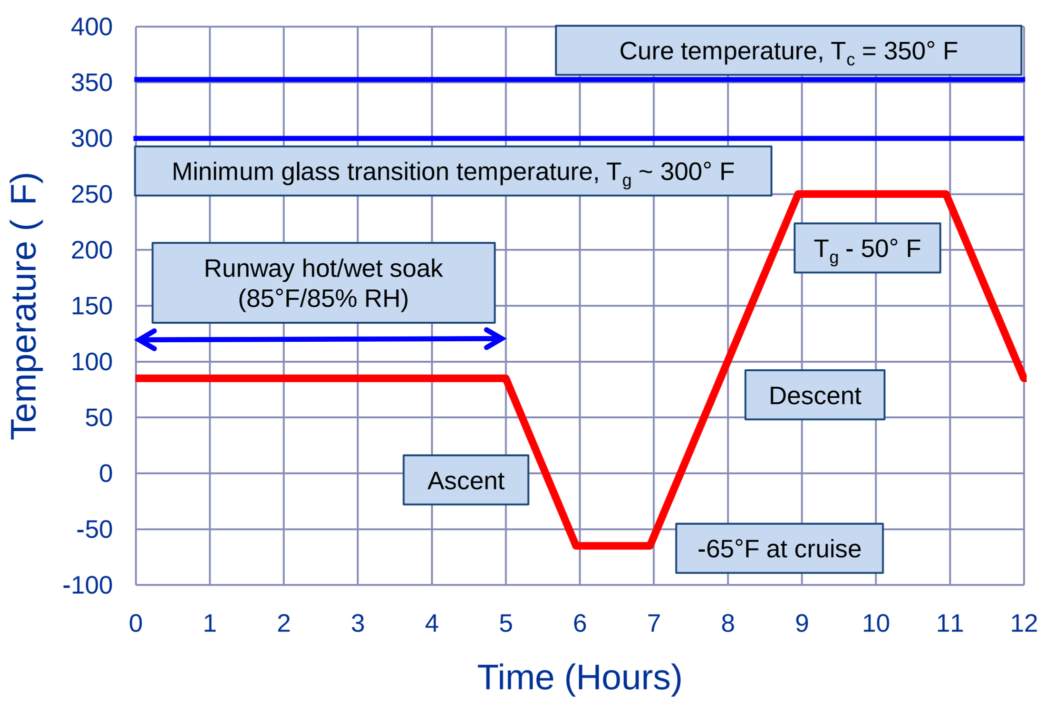
- Impose representative engine aging conditions in a laboratory environment.
- Utilize laboratory test methods to evaluate a wide range of potential changes in chemical, mechanical, physical, and impact properties due to aging.

Approach:

Impose a hygro-thermal cycle that represents the fan section environment during a flight cycle

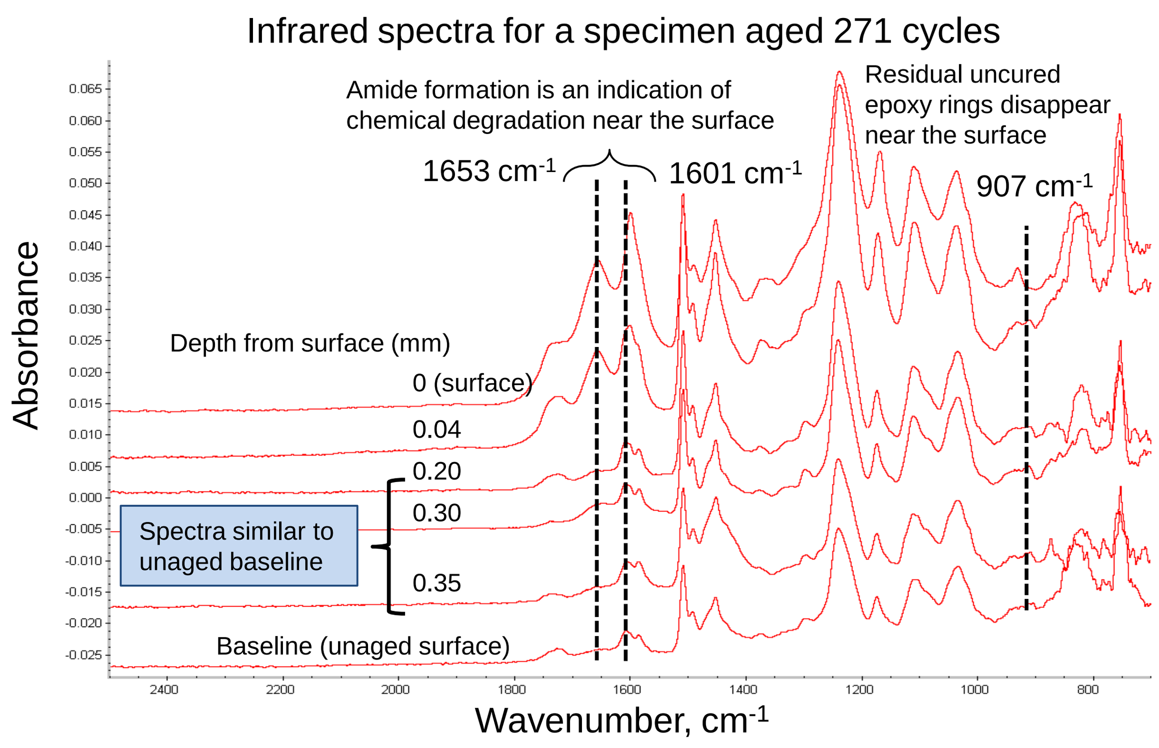
Measure changes in resin properties
- Glass transition temperature (DMA, DSC), density (DSC), chemical structure (FTIR), embrittlement (tension)

Measure changes in composite properties
- Microcracking
- Mechanical properties
- Impact penetration threshold



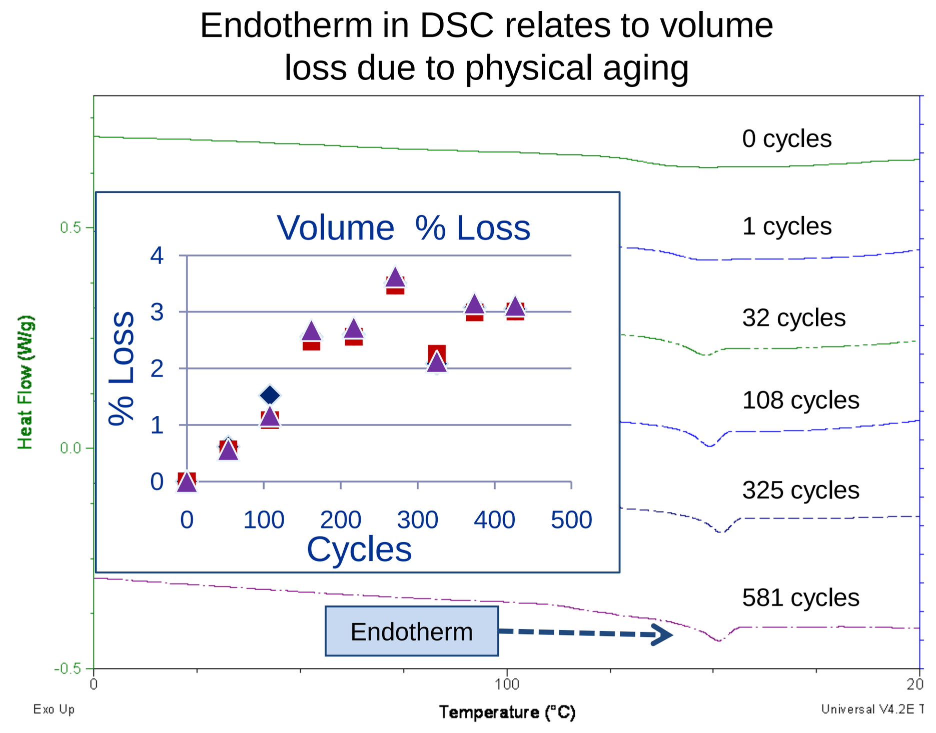
Aging Cycle Set-Points

An aging cycle was chosen to represent a possible set of environmental conditions that could be present in an engine fan section. The set-points of the chosen cycle are shown above.



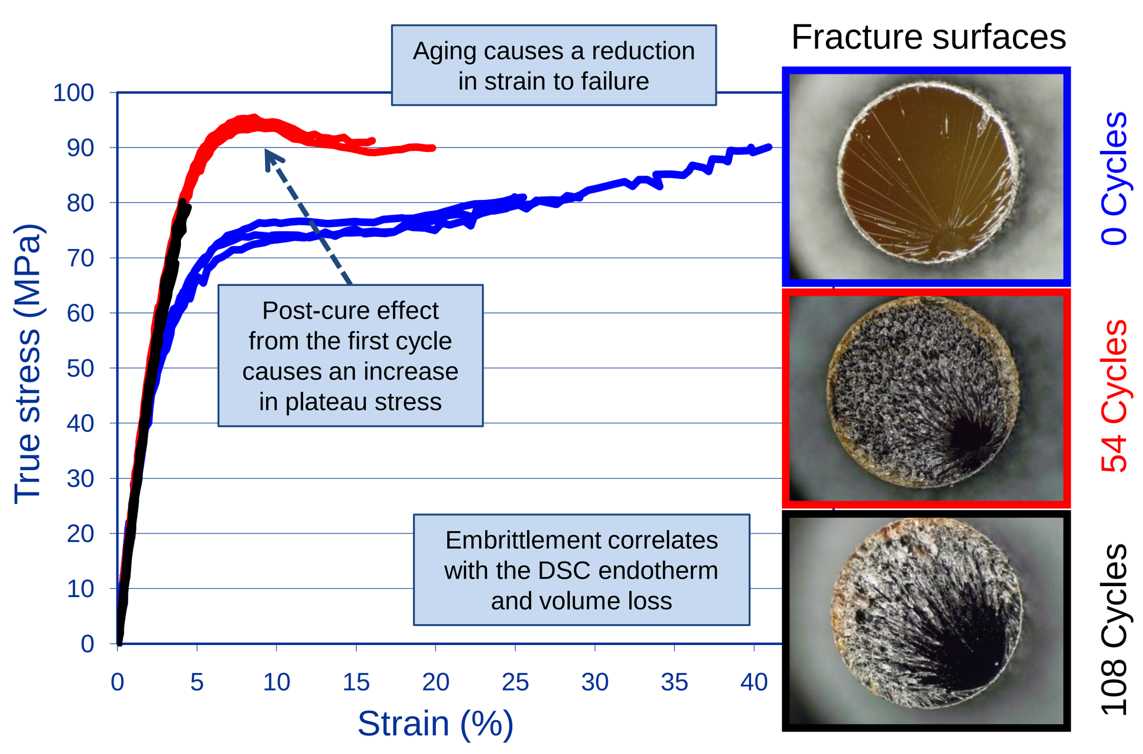
Resin Chemical Aging

Aging effects that change the chemistry of the resin are confined to the surface of the material. The resin used for the results presented here are Epon® E862 with W hardener.



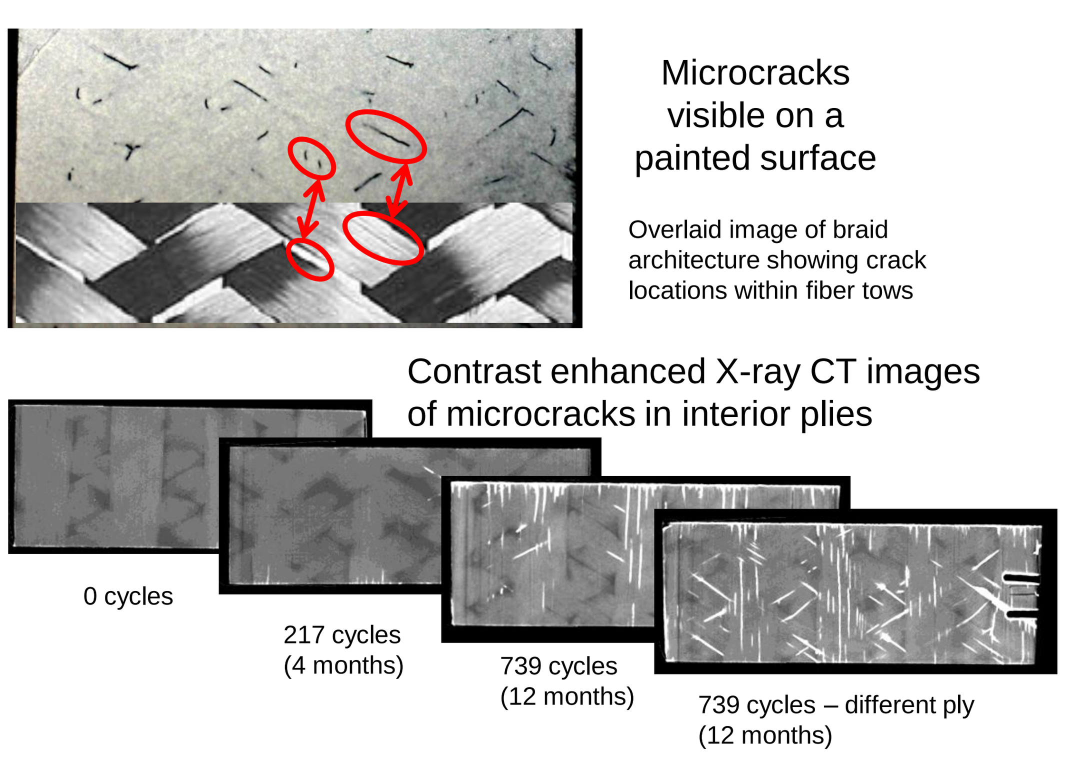
Resin Physical Aging

Physical aging is a process by which the material shrinks, becoming more dense. This aging process can result in resin embrittlement. The development of an endotherm in the DSC data is an indication of physical aging.



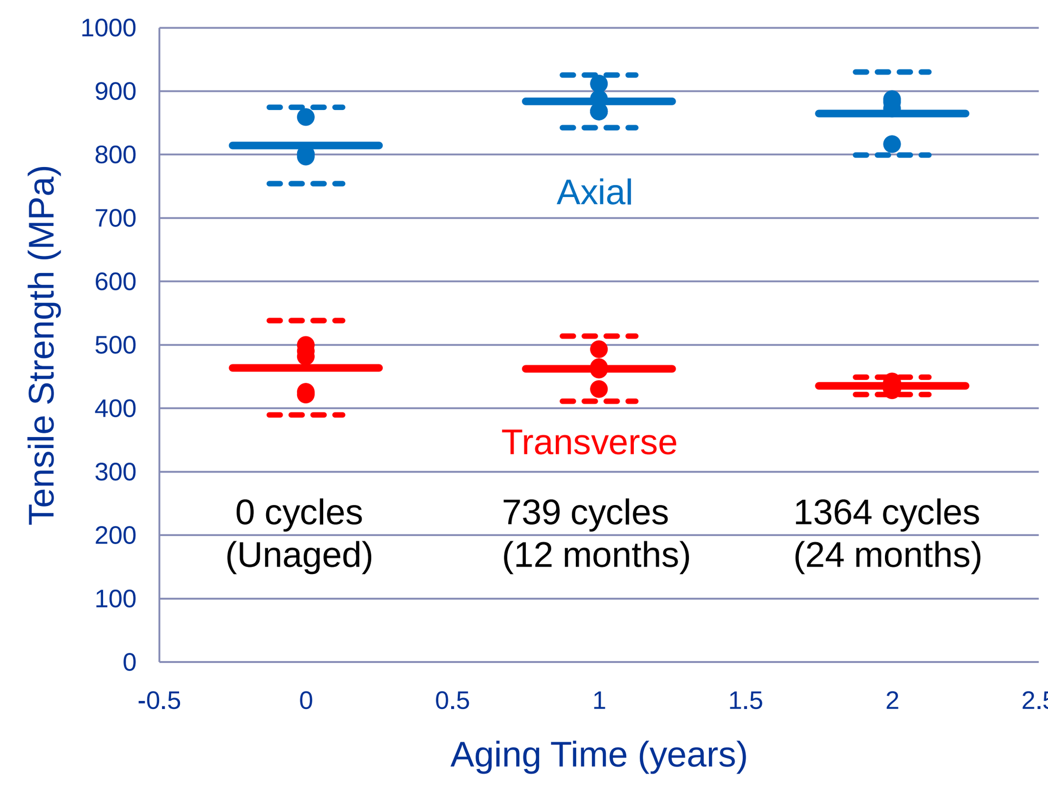
Resin Mechanical Response

Tensile test results show an embrittlement that occurs as a result of the hygro-thermal aging. This embrittlement is shown by reduced strain to failure and changes to the fracture surface.



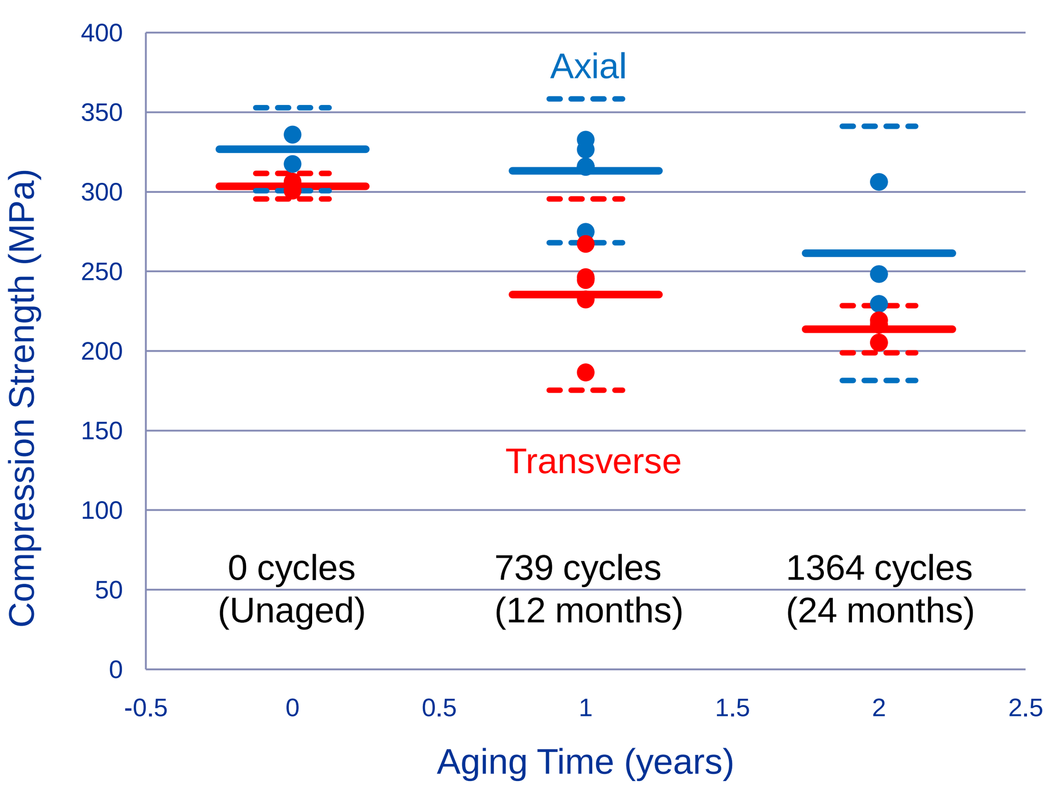
Composite Microcracking

Microcracks (transverse fiber tow splits) develop during aging both on the surface of the composite as well as throughout the interior of the 6 layer specimens. The surface of a non-loaded specimen and a series of contrast enhanced X-Ray CT images are shown. The composite for the results presented here consists of Epon® E862 and 2D triaxial braided Toray T700s carbon fiber.



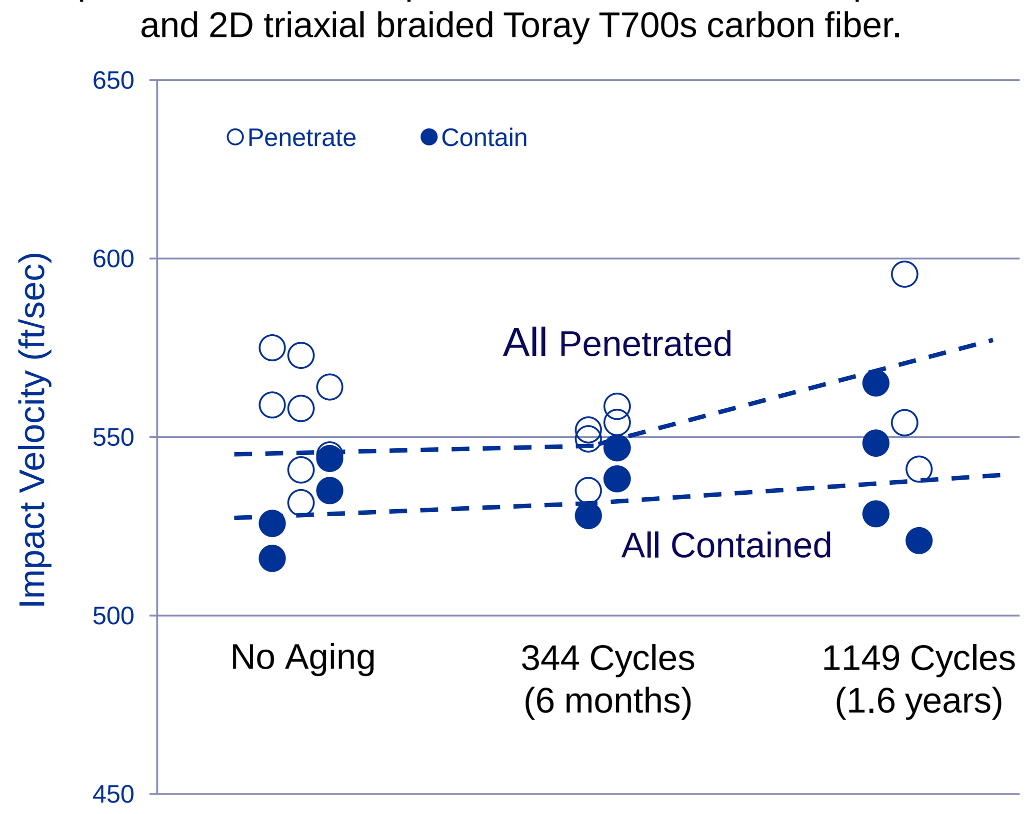
Composite Tension Results

Tension failure stress is plotted for 3 different aging conditions. No significant trend is observed up to 2 year of aging. Note that the transverse tension test is known to produce lower than expected results because of test method deficiencies. This is being investigated separately. Solid lines are the mean and dashed lines are two standard deviations from the mean.



Composite Compression Results

Compression failure stress is plotted for 3 different aging conditions. A trend toward strength reduction may be present but due to limited material availability and scatter, a statistically significant conclusion can not be drawn. This matter is being investigated separately. Solid lines are the mean and dashed lines are two standard deviations from the mean.



Impact Results

The threshold for impact penetration shows no significant change after 1.6 years of aging. Penetrated panels are shown with open circles, and non-penetrated with filled circles. The test method utilizes a blunt projectile and a circular, fixed boundary condition.

Conclusions:

- Mechanisms have been identified in the resin that lead to brittle response. These include post-cure, oxidation, and physical aging.
- Aging causes microcracking in the composite, but the microcracking does not cause a significant reduction in tensile strength. A possible reduction in compression strength needs further investigation.
- Aging does not have a significant effect on impact penetration threshold.
- Additional materials are currently in various stages of aging.

NASA Aviation Safety Annual Technical Meeting
St. Louis, MO May 10 – 12, 2011