E. Low-Cost Test Methods for Advanced Automotive Composite Materials: Creep Compression Fixture

John M. Henshaw
The University of Tulsa
600 South College Ave.
Tulsa, OK 74104
(918) 631-3002, fax:(918) 631-2397, e-mail: john-henshaw@utulsa.edu

Greg Baxter
The University of Tulsa
Mechanical Engineering, KEP L185
600 South College Ave.
Tulsa, OK 74104
(918) 631-2521; e-mail: greg-baxter@utulsa.edu

Ron Cooper
Ford Motor Company
Ford Research Laboratory
MD 3135/RIC Bldg.
P.O. Box 2053
Dearborn, MI 48121
(313) 322-3424; e-mail: rcooper3@ford.com

ACC Project Contact: Dan Houston
Ford Motor Company.
20000 Rotunda Dr., MD 3182 SRL, P.O Box 2053
Dearborn, MI 48121-2053
(313) 323-2879, fax: (313) 323-0514, e-mail: dhousto2@ford.com

Technology Area Development Manager: Joseph A. Carpenter
(202) 586-1022; fax: (202) 586-1600; e-mail: joseph.carpenter@ee.doe.gov
Field Technical Manager: Philip S. Sklad
(865) 574-5069; fax: (865) 576-4963; e-mail: skladps@ornl.gov

---

Contractor: U.S. Automotive Materials Partnership
Contract No.: FC26-02OR22910

Objective

- Design and develop low-cost, reliable fixtures and methods for the characterization of compression creep behavior of automotive composites with and without environmental exposure. Confirm results generated by the new fixture with those from conventional testing systems.
- Incorporate the fixtures and methods in the above objective into industry-standard test methods for automotive composites.
- Using results of short-term tests, develop predictive models for lifetime property degradation.
- Investigate the fundamental damage mechanisms in polymer-matrix, carbon-fiber and E-glass composites as a function of specific, varied mechanical loading with concurrent environmental exposure.

Approach

- Design and develop a compact compression creep test fixture system and confirm its performance.
- Use the new fixture system to develop a compression creep database.
- Develop a standard procedure for compression creep testing using the new system.

Accomplishments – FY 2005

- Final fixture prototype developed and extensively tested.
- Test fixture meets all design and project requirements.

Future Directions

- Continue to evaluate and document fixture performance – final tests in advance of project end date.
- Document standard test procedures.
- Project end date: 12-31-2005

Introduction

Because of insufficient information on the long-term durability of lightweight composite materials, reliable methods and models requiring relatively short-term tests are essential to composites achieving their full potential in the automotive industry. The purpose of this project is to develop simple, low-cost fixtures and methods for the creep and creep-rupture characterization of automotive composites, and confirm the in-situ creep test fixture results with those obtained using conventional testing methods.

Initial Design Concept for the Compression Creep Fixture

Several design specifications were targeted when developing the initial prototype fixture during the first year of this project. The creep compression fixture must simulate in-service loading conditions by allowing the specimen to be exposed to various automotive environments. The fixture must also be lightweight, compact, relatively inexpensive, and portable compared to industry standard dead-weight creep testing fixtures. Lastly, the data generated by the fixture should be of design quality while comparing favorably to ORNL (Oak Ridge National Laboratory) and literature data. A successful fixture will also be corrosion resistant, capable of testing ASTM standard compression coupons, and exhibit no signs of specimen buckling (less than 5% bending).

Prototype 3A Creep Test Results

Test results with the third-generation prototype (Prototype 3) were extremely encouraging, as reported in detail in the 2004 annual report. Previous Prototype 3 test results involving glass-fiber composites in creep compression generally exhibited less than 5% bending. All previous results from prototypes 1 to 3 can be viewed in the 2003 and 2004 annual reports. Modifications made to Prototype 3, resulting in Prototype 3A, have mainly been done to allow the Prototype 3A to be adapted to a variety of external-loading machines (as noted above).

Summary of Prototype 3A Design Detail

The third-generation prototype currently under development utilizes a four-pin design where the specimen fits inside two compression blocks that are pressed toward each other by load-reversing pins (Figure 1). The ends of the pins are threaded into a connecting bracket that, in turn, mounts to either a clevis joint on a spring-loaded moment arm, Figure 5 (a fixture developed in a previous project), a standard load frame (not shown), or a custom load-multiplying creep-rupture fixture developed in a previous project (Figure 2). Prototype 3A is capable of testing compression specimens that are 5 inches long, which is the ASTM standard length. Earlier prototypes utilized an undersized specimen. The prove-out testing continued with evaluating performance of unreinforced poly-vinyl chloride

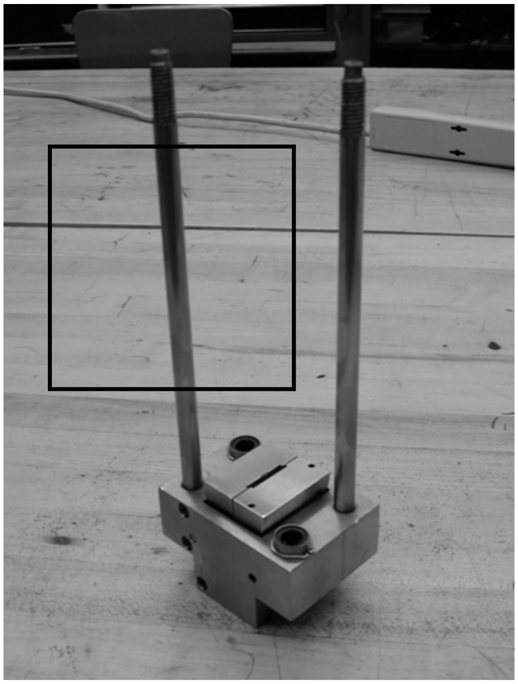

Figure 1. Disassembled creep compression fixture showing one of two load blocks, two of four load-reversing pins, and slot for inserting specimen (inset shows assembled fixture)

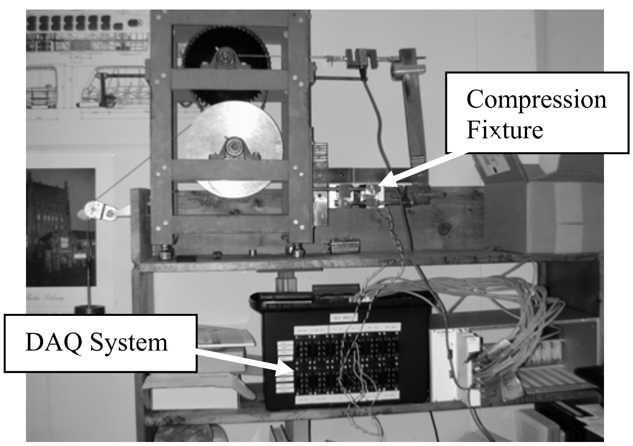

Figure 2. Custom load-multiplying frame with Prototype 3 compression fixture

(PVC) specimens. Results from these tests, while generally good, produced some unexpected results.

At the beginning of some tests, the initial percent difference in strain was inconsistent from one test to another on the same material. It was determined through repeated testing that, in the assembling of the fixture and installation of the specimen, critical variances sometimes occurred.

Since the Prototype 3A compression fixture is made up of many components, differences in assembly sequence were investigated. When disassembled, the fixture is comprised of 6 critical components. When assembled, there are 16 ways in which these pieces can fit together to make the same fixture. It was found that of these 16 configurations, only 4 produced favorable bending results. This was determined by manually compressing a PVC specimen and, as the wedges slid into the compression blocks, visually inspecting bending of the specimen.

Using the 4 best setup configurations, creep compression tests were conducted on PVC and polycarbonate compression specimens. Since these plastics lacked fiber reinforcement, bending loads were immediately evident. Figures 3 and 4

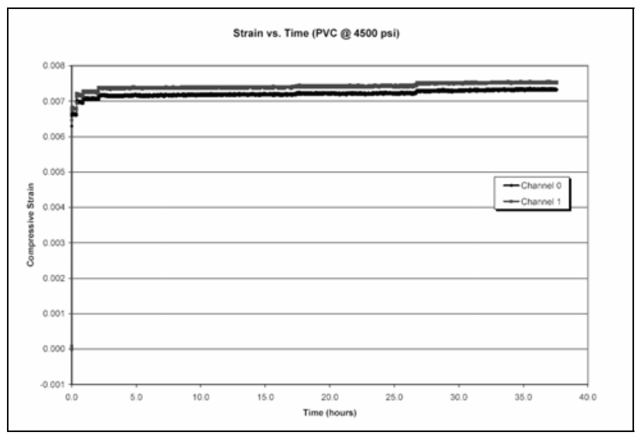

Figure 3. Plot of compressive strain for PVC at 4,500 psi for 38 hours

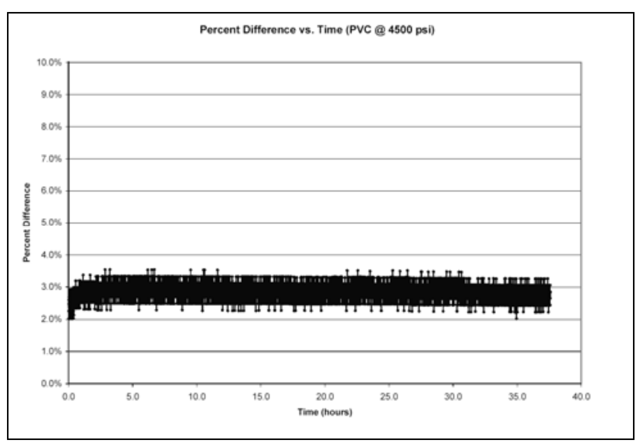

Figure 4. Plot of percent difference for PVC at 4,500 psi for 38 hours

demonstrate the creep compression performance of PVC under 4,500 psi for 38 hours. Figure 3 shows the total strain on a PVC specimen as a function of time, while Figure 4 shows the percent difference in strain between the two sides of the specimen throughout the duration of the test. Note that the percent difference in strain varies between about 2.5% and 3.5%, well under the maximum of 5%. The creep compression test from Figures 3 & 4 was conducted using the compression fixture in the creep-rupture fixture as shown in Figure 2. This creep-rupture fixture is capable of outputting a load 180 times its input. A hanging weight is applied as the input and the load-multiplier arm pulls on the reverse-loading pins in tension causing the compression blocks to come together, putting the specimen wedged within under compression. Because the weight is allowed to hang, the loading is constant.

Constant-Load Testing

As noted above, Prototype 3A is identical to Prototype 3 except for a few modifications to allow it to fit in a variety of external loading frames, such as the tensile creep constant-tress frame (Figure 5). Two modifications were incorporated into the new fixture to simplify loading the sample in the frame and fitting the fixture into the limited working envelope of the constant-stress frame. Pins to secure the cross-head to the loading rods instead of bolts were used to ease loading the fixture into the frame and eliminate uneven loading that can occur if the bolts are not threaded to identical positions on each loading rod. A bolt was added external to the original workspace of the constant-stress fixture to secure one of the two cross-heads. The addition of this bolt allowed the fixture to be more easily loaded into the frame.

A test of the fixture's ability to maintain a constant load was conducted because both modifications created changes to the original fixture loaded in the creep-rupture frame. This was accomplished by replacing the test specimen with a compression load cell (Figure 6). The load cell was compressed to a 506 lbf clamping load and held for 500 hours. The load remained within 10 lbf of 506 lbf (within ±2%) after 500 hours (Figure 7).

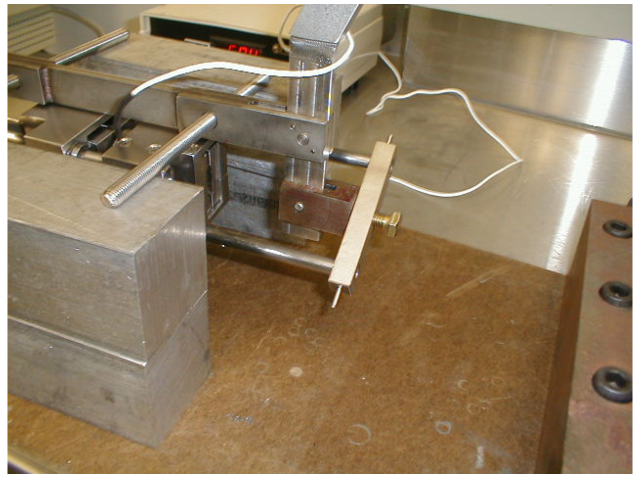

Figure 5. Prototype 3A creep compression fixture modifications to fit in the constant-stress frame

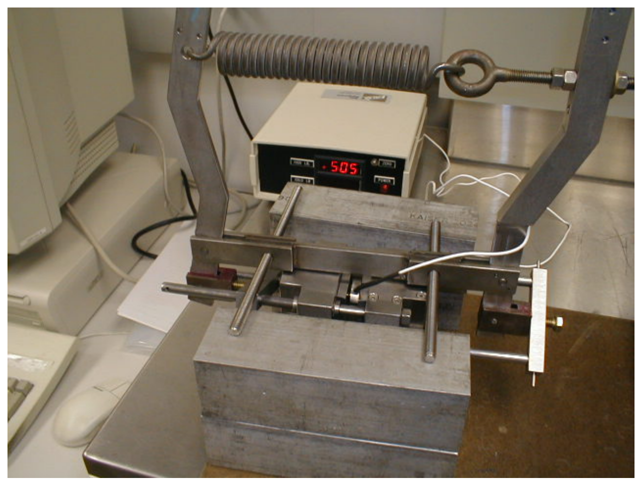

Figure 6. Prototype 3A creep compression fixture static load test

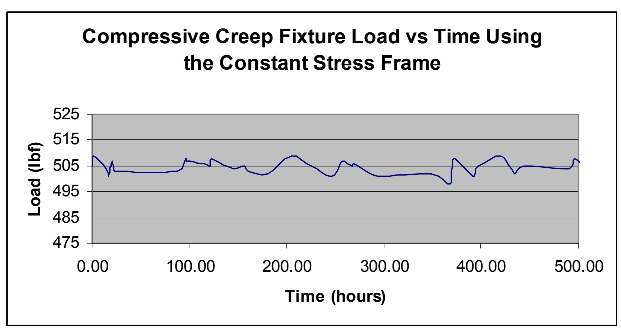

Figure 7. Prototype 3A creep compression fixture load vs. time for a static load of 506 lbf

On-Going/Future Work

- Conduct further creep compression tests in an MTS floor load-frame, comparing results from the two existing fixtures.
- Evaluate creep compression fixture under elevated temperature testing.
- Construct a testing procedure with assembling instructions.

Conclusions

- Controlling assembly of the compression creep fixture is important in terms of ensuring the quality and repeatability of compression test results.
- The current fixture prototype meets design requirements including maximum allowable bending during test (percent difference in strain less than 5%).
- The current fixture maintains applied loads within 2% over long-term testing.