Testing Brief

Long Term Creep and Stress Relaxation Experiments, April 2006

Long Term Creep and Long Term Stress Relaxation Experiments for Rubber and Plastic Materials

Introduction

The objective of the testing described herein is to examine the long-term effect of a constant stress or a constant strain on a plastic or rubber material. These experiments are often performed at elevated temperatures and the data is sometimes used to predict material behavior beyond the time frame of the actual experiment.

There are readily available standards that provide guidance on the use of long term creep data and long-term relaxation data for the prediction of mechanical properties beyond the duration of the experiment. These include:

• ISO standard 11346 Rubber, vulcanized and thermoplastic – Estimation of lifetime and maximum temperature of use from an Arrhenius plot.

• ISO standard 899-1 Plastics - Determination of Creep Behavior - Tensile Creep

• ASTM D 2990 Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-rupture of Plastics

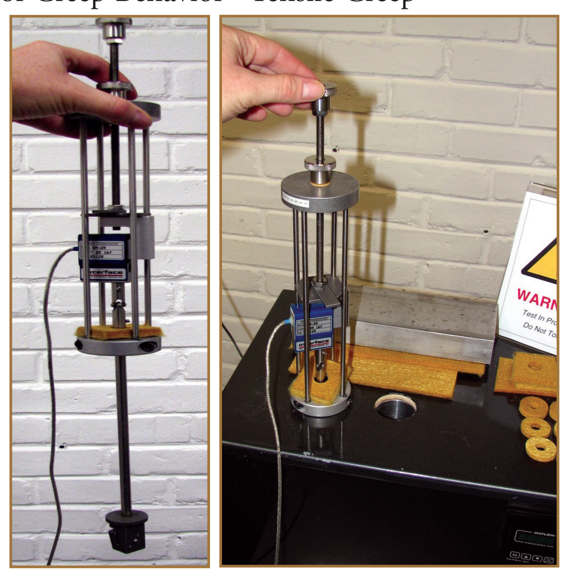

Figure 1, Tesnsile Stress Relaxation Fixture, left, and the same Fixture in an Oven, right

These "long term" experiments typically run for days, weeks or months at a time. They are intended to characterize the irreversible mechanical and chemical changes in the material. There are other "short term" creep and stress relaxation experiments, which typically run less than 1 hour, that are intended to characterize the reversible viscoelastic behavior of materials. The short-term reversible viscoelastic behavior is frequently defined with various mathematical representations of springs and dashpots. These same representations are typically not appropriate for the prediction of long term behavior.

While these experiments are easily characterized by the duration of the experiment, there are significant practical considerations in the design of the experiments. While it is reasonable and cost effec-

Axel Products, Inc.
2255 S Industrial
Ann Arbor MI 48104
Tel: 734 994 8308
Fax: 734 994 8309
info@axelproducts.com
www.axelproducts.com

axel physical testing services

tive to use a universal tensile tester such as an Instron to perform short term experiments, it is prohibitively expensive to tie up these instruments for long periods to perform an individual long term experiment. As such, long term creep and stress relaxation experimental test stands tend to be constructed using manually operated screws to apply stress relaxation strains and dead weights to apply creep stresses. The practical result is that it becomes difficult to obtain useful short-term data with long-term test stands because the method of applying the loading is imprecise.

As a practical matter, structural plastics are characterized with creep experiments and elastomer materials are characterized with stress relaxation experiments.

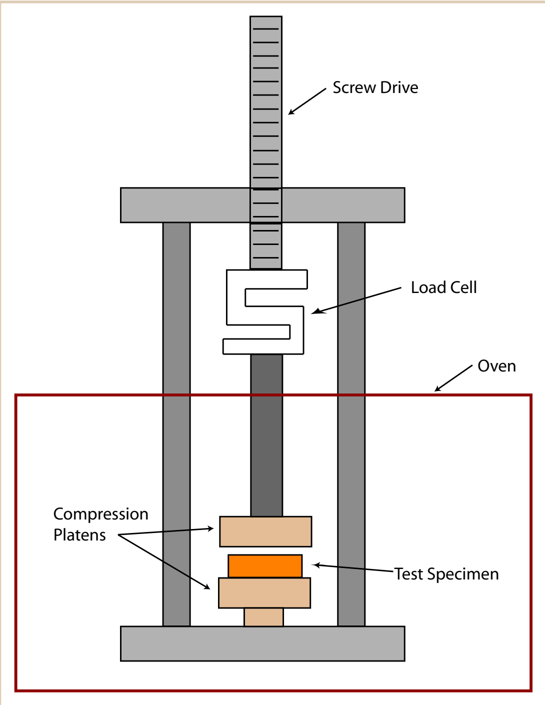

Figure 2, Schematic Diagram of the Compression Stress Relaxation Fixture

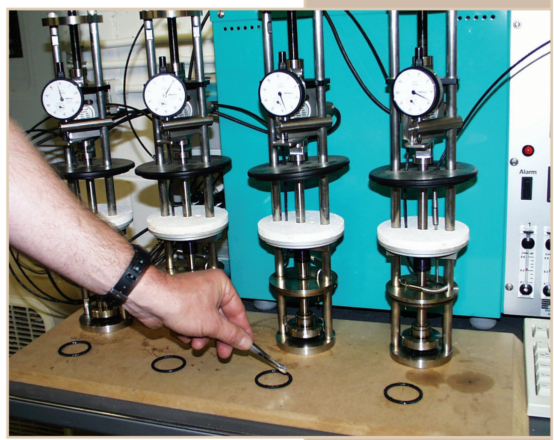

Figure 3, Compression Stress Relaxation Fixtures Manufactured by Elastocon, AB

Long Term Stress Relaxation Experiments

Long-term stress relaxation experiments are typically performed in tension or compression. At Axel Products, these experiments are performed using individual fixtures whereby a screw moves a compression platen or a tensile grip a set distance in order to achieve a particular strain in the material. For tensile experiments, a long rectangular specimen is used and grip travel is the basis for strain. For compression experiments, a cylinder or cube of material is compressed between metal platens and the travel distance of the platens is the basis for strain. Because the grips or platens are moved manually by turning a screw and observing a digital caliper, the loading rate and timing is imprecise. Because grip travel and platen movement can be slightly inaccurate, the accuracy of the set strain is imprecise.

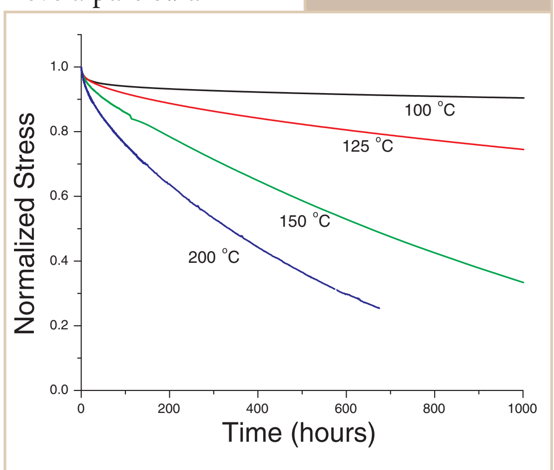

Figure 4, Normalized Compression Stress Relaxation Data

While most of the fixture sits in a block oven at the desired temperature, part of the fixture extends out of the oven such that a strain gage load cell sitting outside of the oven can continuously measure the force on the specimen. A central data collection system is used to monitor the change in force over time.

Long Term Creep Experiments

Long-term creep experiments are typically performed in tension or compression. At Axel Products, these experiments are performed using individual fixtures. Weights are loaded onto a pan and the weight is transmitted through a lever arm into a loading fixture set up for tension or compression.

For tensile experiments, a long rectangular specimen is used and a clip-on strain sensor is used to measure strain directly on the specimen. For compression experiments, a cylinder or cube of material is compressed between metal platens in a compression cage and the travel distance of the compression platen centers is measured

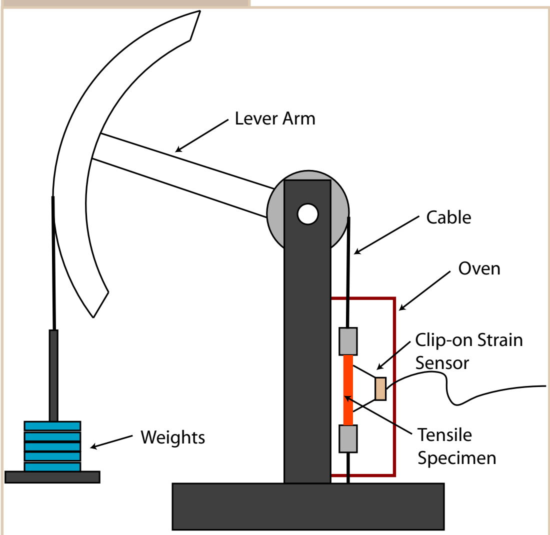

Figure 5, Schematic Diagram of the Creep Test Instrument

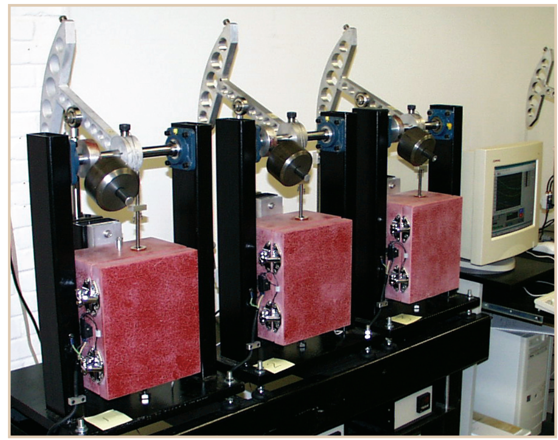

Figure 6, Creep Stands Fitted with Ovens

using a clip-on strain sensor attached to the compression cage center supports inside the oven. Because the weights are gradually applied in the loading system, the loading rate and timing are imprecise. In addition, as the compression cages or tensile grips are loaded, sometimes there is some movement or aligning that takes place, which can create inaccurate strain values.

A central data collection system is used to continuously monitor strain from the clip-on strain sensors.

A Matter of Sequence

Testing at elevated temperature involves other considerations. Heating the test specimen will cause thermal expansion and possibly additional curing. One question is that of sequence; does the specimen get loaded and then heated or does the specimen get heated and then loaded. If the specimen is loaded first, the subsequent heating will cause dimension changes (change in gauge length) due to thermal expansion as well as creep effects; in other words, we observe simultaneous softening and expansion. While this can result in messy data that is hard to interpret, some researchers prefer this approach because it may more closely mimic the in-service condition of the material application. If the specimen is heated first and then loaded, the effect of thermal expansion on the stress results is negated.

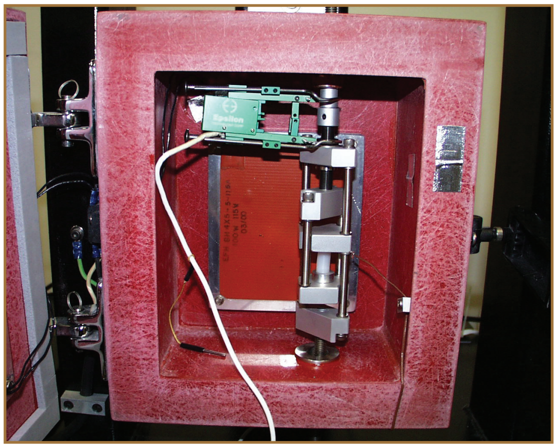

Figure 7, Compression Creep Fixture Fitted with Extensometer in Oven

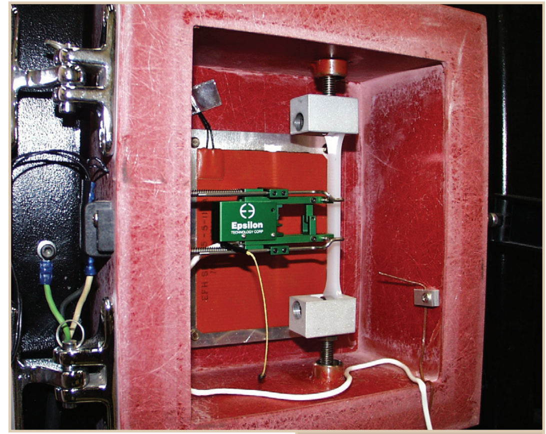

Figure 8, Tensile Creep Fixture Fitted with Extensometer in Oven

Summary

Long term creep testing and long term stress relaxation testing can provide meaningful data for the prediction of long term material behavior. However, because the test methods used to generate this data are typically simple mechanical test stands, short term viscoelastic test results may be compromised.

***For more information*, visit www.axelproducts.com.**

Axel Products provides physical testing services for engineers and analysts. The focus is on the characterization of nonlinear materials such as elastomers and plastics.

Data from the Axel laboratory is often used to develop material models in finite element analysis codes such as ABAQUS, MSC.Marc, ANSYS and LS-Dyna.

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www.axelproducts.com

axel
physical testing services