Testing and Analysis

Measuring the Shear Properties of Plastic Materials for Finite Element Analysis

Introduction

Testing for finite element analysis requires experiments that put the material in a known state of strain. Material constants are simple to extract such that there is a closed form analytical solution which describes the stress-strain condition in the test specimen. This allows us to generate experimental data that may be used to calibrate the material constants in material constitutive models.

The stress-strain relationship during pure shearing is a desirable measurement. This document describes an experiment used at Axel Products to measure the structural strength of plastic and plastic composite materials in a pure shear strain state during loading and unloading and across a broad range of temperatures.

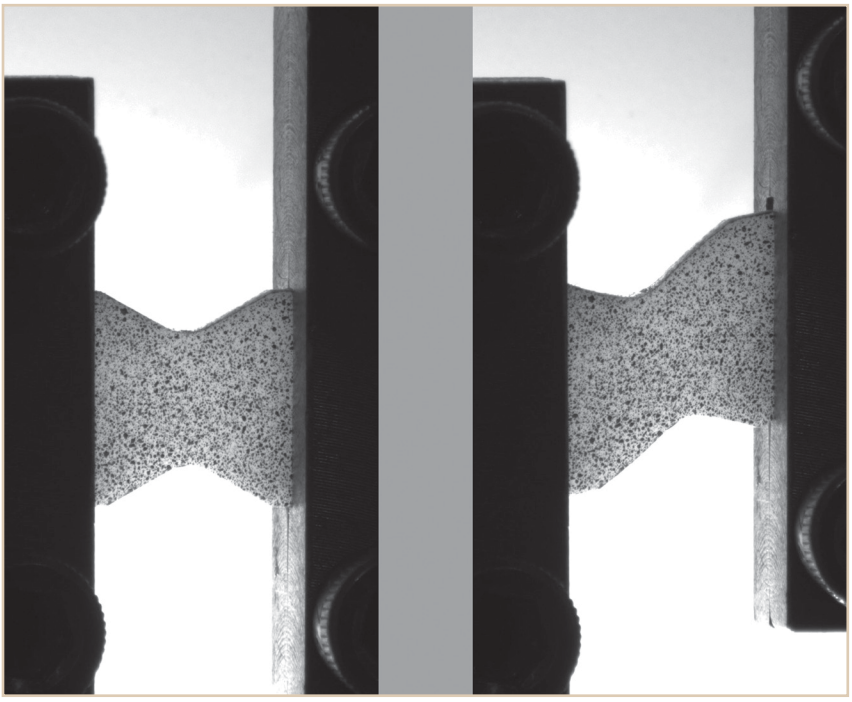

Figure 1, Plastic shear specimen unstrained on the left side, strained on the right side.

The Experiment

A modified Iosipescu test specimen is loaded using an Arcan type of test fixture. The test specimen and loading fixture is taken directly from the work of Bhargava and Zehnder.(1) Direct strain measurement is added using a commercially available 3D digital image correlation system.(2) Similar use of digital image correlation is outlined in Totry, González & Llorca.(3)

This testing is not failure oriented. The intention of the experiment is to model the behavior of the material in the working range of strain and stress in the application.

The Test Specimen

The test specimen is designed to provide a region of pure shear between the notches. The specimen may be cut from plaques.

The Test Instrument

The simple shear experiment is typically used with an Instron physical test instrument capable of operating across a wide range of strain rates. The instrument also has the ability to reverse based on a strain trigger.

Strain Measurement Using Digital Image Correlation

In this experiment the region of interest is a narrow region between the notches. This is where the stress is intentionally localized to create a pure shearing condition. The strain must be measured in the region of the test specimen where the desired strain state is achieved. For very rigid materials users have bonded strain gages. In this case, an optical surface strain measurement technique is used. To do this, a speckle pattern is painted onto the specimen surface and a small region is identified and the shear strain is measured using digital image correlation. The system used at Axel Products is the Vic 3D Gage system produced by Correlated Solutions, LLC. The system allows the identification of a small region on the test specimen to be used. Furthermore, the calculated shear strain can be output as a continuous analog signal during the experiment. This provides the ability to use the shear strain to trigger the tensile testing instrument to unload the test specimen providing valuable load-unload data.

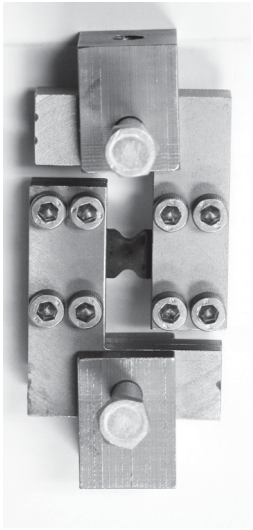

Figure 2, Plastic shear specimen holding fixture.

A three dimensional digital image correlation system with 2 cameras is able to accurately capture shear strain measurements if they occur out of the plane that the specimen starts in. This is important because there is the posiblity that the specimen holding fixture may rotate slightly and also because some specimen shearing may be somewhat out of plane.

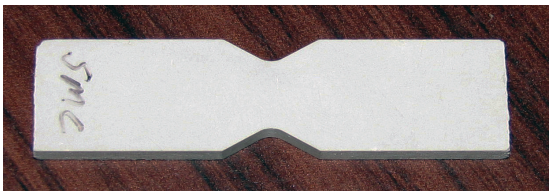

Figure 3, Plastic shear specimen.

The Environmental Test Chamber

A special environmental chamber is used to accommodate hot and cold testing. Testing between -40 and 150C is typical. The chamber has optical glass to accomdate the 2 cameras from the digital image correlation system and it also has special internal light sources for front lighting and back lighting test specimens.

Summary

Shear testing of plastics for the purpose of fitting material models in finite element analysis requires an experiment with a defined pure shear condition of strain under carefully considered loading conditions. The stress and the strain need to be measured where the pure shear condition is achived. The experiment descibed herein appears to meet this need.

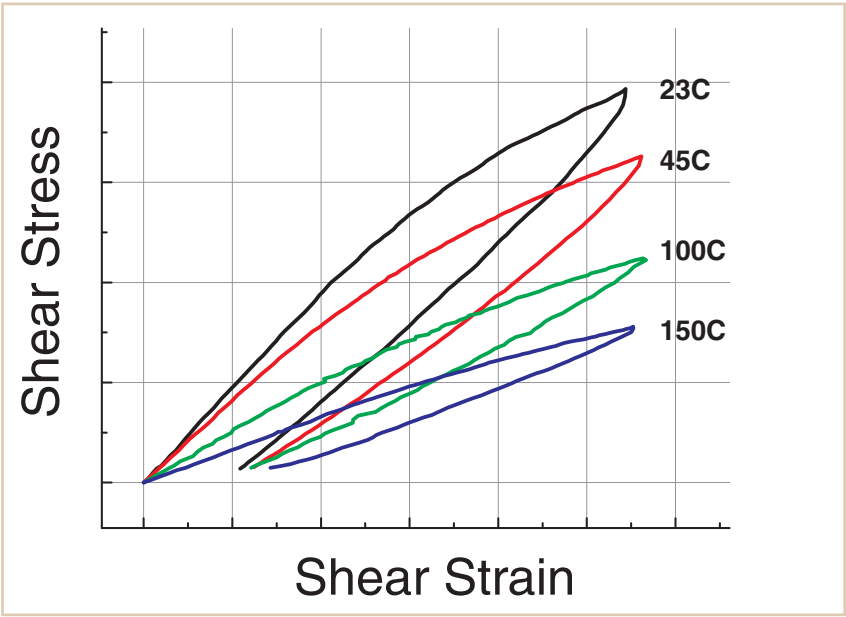

Figure 4, Shear stress strain loading unloading curves at several temperatures.

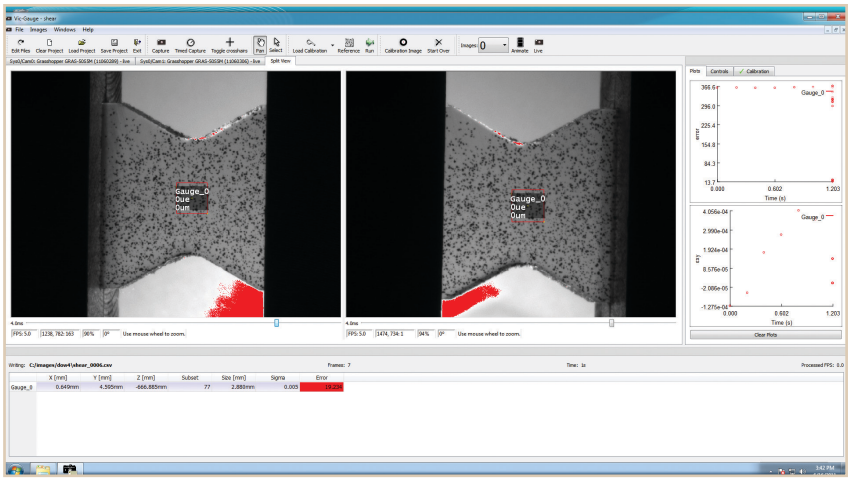

Figure 5, Digital image correlation software screens showing the left and right camera images with the placement of the virtual shear gage.

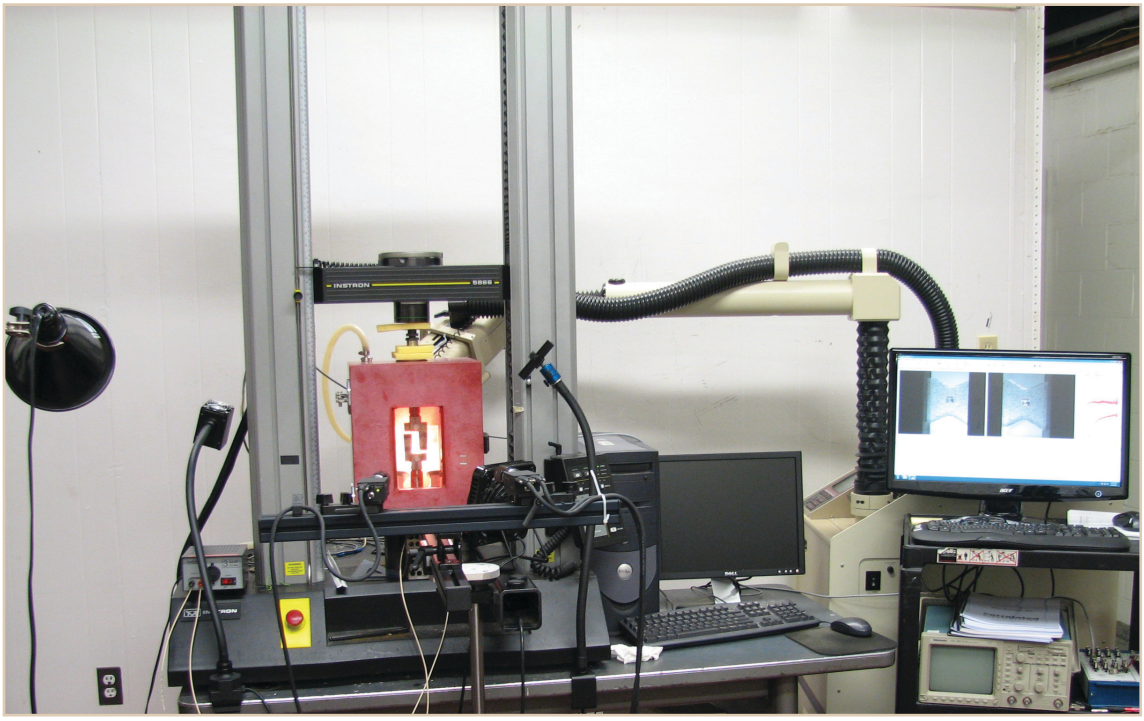

Figure 6, The complete experimental test system with environmental chamber, lighting, grips and cameras.

References:

1. Peeyush Bhargava and Alan T. Zehnder, "High temperature shear strength of T650-35 / HFPE-II-52 polyimide matrix unidirectional composite," Experimental Mechanics, 46, pp. 245-255, (2006)

2. Correlated Solutions, Inc., Columbia, SC , http://www.correlatedsolutions.com

3. Totry, Essam and González, Carlos and & Llorca, Javier, "An Experimental and Numerical Analysis of the V-notched Rail Shear Test to Measure the Shear Properties of Fiber-Reinforced Polymers," CompTest2008, October, 2008, University of Dayton, Dayton, USA

Company Profile:
Axel Products, Inc. is a physical testing laboratory specializing in the characterization of elastomers and plastics for engineers and analysts. The company was founded in 1994. Materials are shipped in and test data is digitally delivered. Companies around the world use the specialized services of Axel Products to obtain the stress and strain data to support engineers and users of finite element analysis (FEA) software such as ABAQUS, ANSYS, DIGIMAT, Marc, ALGOR and Dyna.

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.

Axel Products, Inc.

2255 S Industrial
Ann Arbor MI 48104
Tel: 734 994 8308
Fax: 734 994 8309
info@axelproducts.com

axel
physical testing services