Mechanical Characterization of Strain-Rate-Dependent Polyurethane foams

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Introduction

The primary goal of this project was to develop methods to support the creation of a constitutive model for strain-rate-dependent foams. These foams, such as PORON XRD, are often used for impact protection and other similar mechanical tasks; however, their behavior is poorly understood, and robust continuum models are not currently sufficient.

This project utilized DIC (Digital Image Correlation) to measure strain of foam specimens, and this was correlated with load data from an Instron load frame. The bulk of the work consisted of finding the configuration that would work best for data collection, with different speckle patterns, cameras, lenses, and framerates being explored. This project aimed to collect data at the 10^{-1}, 10^{-2} , and 10^{-3} 1/second strain rates

Materials

Cameras:

The cameras used for this project were a Nikon D40, a standard consumer DSLR, and a PCO.edge5.5, a high-end scientific-grade camera. Specs are shown below.

PCO.edge5.5	Nikon D40
• 2560x2160 pixel resolution • 100 FPS maximum framerate • Dynamic range: 30000:1 • Low noise	• 6.1 MP resolution • 2.5 FPS max framerate

Foam Specimen Parameters:

Parameter	Compression Sample	Tension Sample
Thickness	9.5 mm	6.5 mm
Density	20 lb/ft^3	20 lb/ft^3
Direction of force	Through thickness	Along sheet
Specimen Geometry	~1cm^2	Dogbone, 1” g.l.

Machine:

This program used an Instron 5942 500 N capacity single column load frame, located in Prince Engineering Lab. Data was recorded using a computer equipped with Bluehill 3 data collection software.

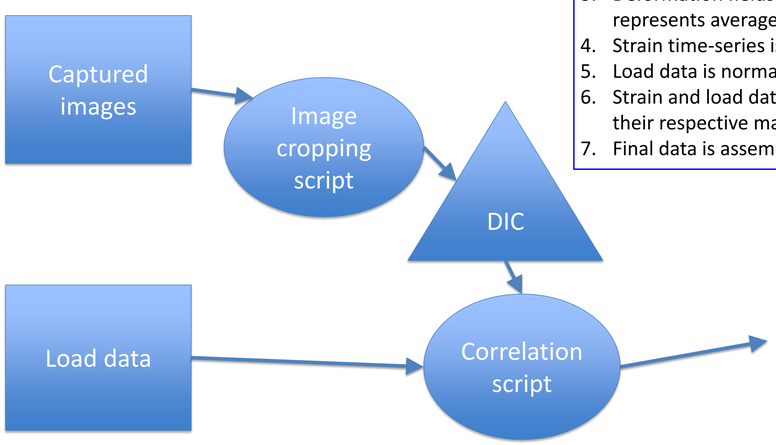
Other Materials:

Vaseline, as well as Dixons #2 Graphite, was used to lubricate the working stage. Both airbrush paints and ordinary spray paints were used to apply the speckle patterns.

DIC Process

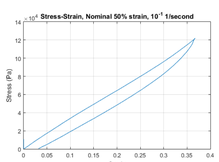
Inputs:

- Raw images from camera
- Load cell data from Instron
- Configuration information
  - Cross-sectional area
  - Framerate
  - Input and output folders
  - Orientation
  - Cropping coordinates

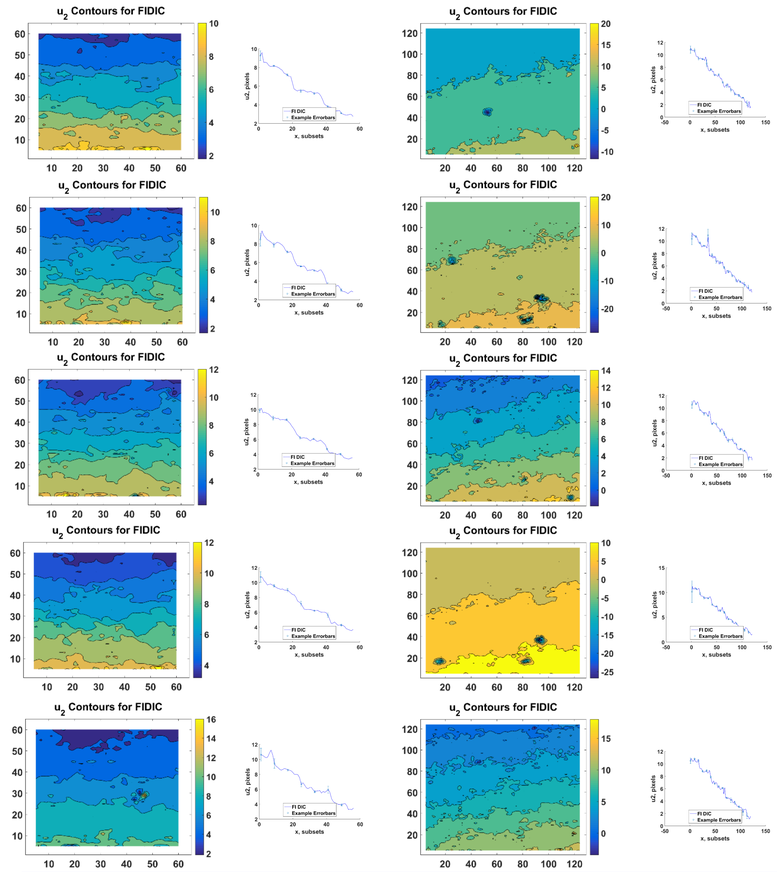


Approach:

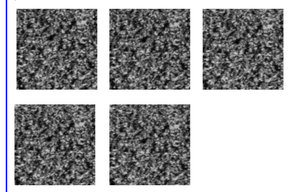
1. Images are cropped and aligned such that motion is parallel to vertical axis.
2. FIDIC (Fast Iterative Digital Image Correlation) is run on the image sets, deformation fields are produced
   1. FIDIC produces guesses for deformation, and continuously refines guess.
3. Deformation fields are fit by a plane; slope of plain represents average strain
4. Strain time-series is assembled
5. Load data is normalized
6. Strain and load data are correlated in reference to their respective maxima
7. Final data is assembled



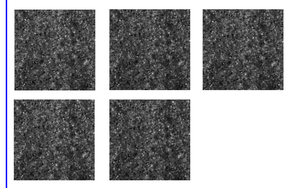
Speckle Pattern Performance



To the left can be seen the results of DIC on compression images taken with the Nikon D40. The left column is white-on-black-patterned foam, applied with an airbrush. The original photos are seen below.



The right column was made with images taken with the same camera, with foam in compression patterned with a simple application of black spray paint. Included below are the original photos.



The contour plots show deformation plots for the vertical direction, and the line plots beside them show a slice of that data taken from the middle. Note that the white-on-black pattern yielded much smoother plots.

Example Results