John Z. Duling Grant Final Report

Name: John Goodfellow, Ward Peterson, Mark Hoenigman, and Gregory Dahle, PhD

Organization: BioCompliance Consulting, Inc. (Project Lead)

Project Title: Characterizing Branch Failure Modes

Grant #: 13-JD-01

PROJECT SUMMARY

This investigation was intended to advance understanding of the science of tree biomechanics, and in particular issues related to the structural integrity of trees. Branch specimens where harvested and prepared for testing, A test jig was fabricated and use to support the specimen during load testing. The ARAMIS stereo photogrammetric system was used to record branch strain, deflection, and deformation data and evaluate itsusefulness.

The load test method and test jig design proved useful and were demonstrated at ISA Tree Biomechanics Week II. The test jig was been donated to West Virginia University and continues to support Dr Dahl's work on tree biomechanics using the ARAMIS system. A more robust version of the test jig has been fabricated by the Morton Arboretum and is being used by Dr Miesbauer in tree biomechanics studies.

STATEMENT OF PROBLEM

Branch and tree failures present risk to the safety of practicing arborists and the general public, and are a leading cause of power outages.

Traditional instruments such as fiber strain gauges have not been effective in measuring shear. The linearity of a conventional fiber strain gauge does not allow for monitoring lateral strains or shear stresses. Because of instrument limitation no measurement of tangential alignment with the neutral plane or the effect of torsional loads has traditionally been made.

Use of 3D photogrammetric ARAMIS software make it possible to characterize deformation due to tension, compression, torsion and resulting shear as a branch is loaded to failure. This project involves application of the advanced structural analysis tools used by NASA in developing a quantitative model of the mechanisms at play during the structural failure of branches.

Objectives of Research

The project had three objectives:

1. To develop experimental methods for evaluating the load-response characteristics of branches, to the point of ultimate failure.
2. To support application of the application ARAMIS stereo photogrammetry system to tree biomechanics.
3. To further our understanding of the branch failure process as the branch progresses from elasticity to plasticity, and ultimately to fracture.

Significance of Project to Arboriculture Industry
Beyond the two objectives related to research methods, the project was intended to increase understand of the distribution of stresses and strains (elastic characteristics) within branches subjected to increased loading. In doing so the investigation further advanced understanding of the branch failure process and will help arborist assess the relative degree of risk of branch failure

Experimental Work

A conceptual design for the test jig was developed by BioCompliance. That design as refined, and the test jig was fabricated by Mark Hoenigman. Branch specimens were donated and harvested by Davey Tree Surgery from their research farm in June 23 & 24, 2013. These specimens were prepared by whitewashing them, and subsequently patterned with stochastic black speckling spatter.

Specimens were transported to the WVU Wood Science Shop in Morgantown WV, and testing occurred June 25-28, 2013.

Data were captured via two ARAMIS systems, one owned by WVU Urban & Community Forestry and the second by Trilion the USA ARAMIS supplier. The WVU system was positioned to collect the top portion of the branch and the Trilion system was positioned to collect the bottom portion of the branch. An attempt was made to position the cameras so the field of views overlapped each other. The placement of the camera system(s) is an important concern. Ideally the cameras would be mounted directly above or below the sample. Yet the camera systems were mounted off to the side as there was no physical location to mount on the ceiling, and placing the camera directly under the sample could lead to physical damage of the camera system if a branch crashed to the ground. The two ARAMIS systems were triggered to start at the same time, in the attempt to determine where failure occurred simultaneously on the top and bottom of the branches. Photographs (stages) were taken at a rate of 3 frames per second. Data was post processed to determine strain during the failure exercises.

FINDINGS (MEASURABLE OUTCOMES)

OBJECTIVE 1 – EXPERIMENTAL METHODS

The method used to prepare specimens proved effective. The test jig was successfully used and subsequently has been used as a prototype for a larger jig being used at the Morton Arboretum

OBJECTIVE 2 – USE OF ARAMIS SYSTEM

The ARAMIS camera systems proved to be a very useful and precise means of acquiring measurement data. There was a gathering of knowledge regarding how to utilize the ARAMIS system and how to expedite the application of the background paint and stochastic speckling.

OBJECTIVE 3 – BRANCH FAILURE PROCESS

The tests completed do not conclusive answer if a failure is more likely to occur on the top of a branch or bottom first. Due to the small sample size and variability of the data, no statistical analyses were conducted.

A review of the data shows there were 9 branches that were successfully captured by both the top and bottom camera system during failure exercises. Two branches did not fail and two branches did not have usable data from one camera systems. Examination of the strain data from ARAMIS, it appears that 4 branches failed on the top section first, 2 branches failed on the bottom section first and 3 appeared to fail on both the top and bottom of the branch at approximately the same time.

An important concern that arose during testing was whether stain measured on the outer bark would be the same as strain measure directly on the wood or xylem. The bark from one sample was removed to investigate the application of the white background being applied directly to the freshly exposed xylem. While the white background paint dried and received the stochastic black speckling, it was determined that background paint did not fully adhere to the xylem as it was easily displaced with a light finger touch. Rendering the paint to fitting more like a glove that can move independent of the wood sample.

TREE FUND
Cultivating Innovation

Experience gained during the work funded by this grant lead to a research project that investigated how to dry green wood after bark peeling and whether bark peeling is required to accurately measure strain in the xylem. The data from this subsequent research was collected during the summer of 2014 and is currently being developed into a publishable manuscript.

USE OF GRANT FUNDS

The project was completed with the generous support of in-kind services by the project team:

TABLE 1 IN-KIND DONATIONS THAT SUPPORTED THE PROJECT

Team Member	In-kind support
Greg Dahle, Ph.D.	3 days lab time, WVU Urban & Community Forestry,
John Goodfellow	50 hours direct time
Mark Hoenigman	Time to fabricate the test jig
Ward Peterson	Four day time
Davey Tree Expert Co.	Research tech, specimen harvest and prep. truck & trailer, lodging and meals in Morgantown.

TABLE 2 OUT-OF-POCKET EXPENSES THAT WERE FUNDED BY DULING GRANT OF $7000

Date	cost	Description of Expenses
25-Jun-13	$777.60	Air Fare, SEA-CLE return
26-Jun-13	$11.50	Tolls, OH Turnpike
28-Jun-13	$11.50	Tolls, OH Turnpike
29-Jun-13	$120.23	Off site parking at SeaTac, WallyPark
25-Jun-13	$986.20	materials/costs for Mark Hoenigman to build test jig
1-Jun-13	$200.00	cost to calibrate & modified load cell to provide V output to ARAMIS
25-Jun-13	$800.00	Davey tree crew to harvest specimens at Davey Farm
25-Jun-13	$100.00	misc supplies to prepare specimens - paint, stencils, etc
27-Jun-13	$4,000.00	Tim Schmidt, use of ARAMIS system
Total	**$7,007.03**	

APPENDIX A – IMAGES (UPPER AND LOWER) OF BRANCH PRE AND POST FRACTURE

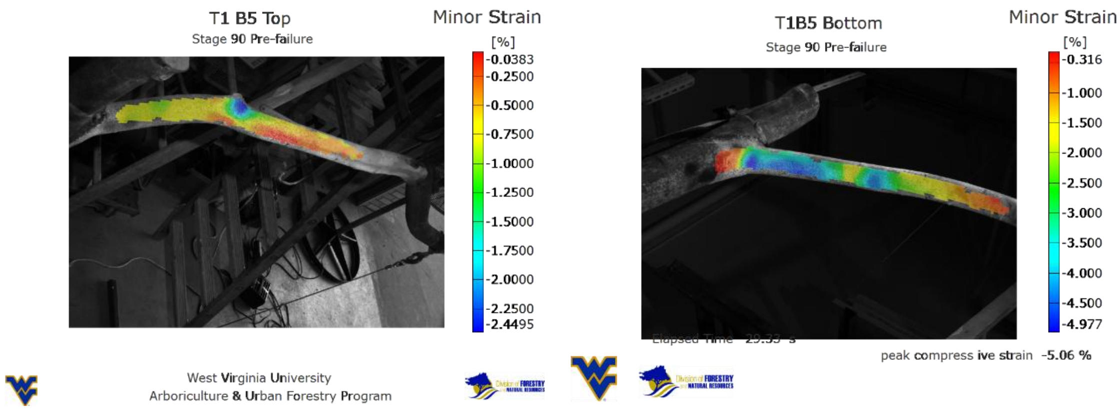

Figure 1. Pre-failure strain mapping along the top and bottom of sample T1 B5.

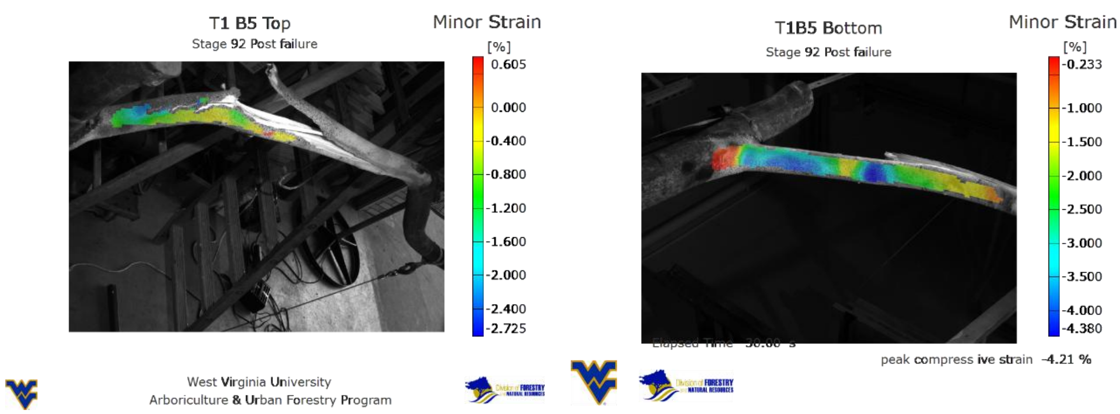

Figure 2. Post failure strain mapping along the top and bottom of sample T1 B5. Note that the failure occurred at a knot along the top portion of the lateral branch.

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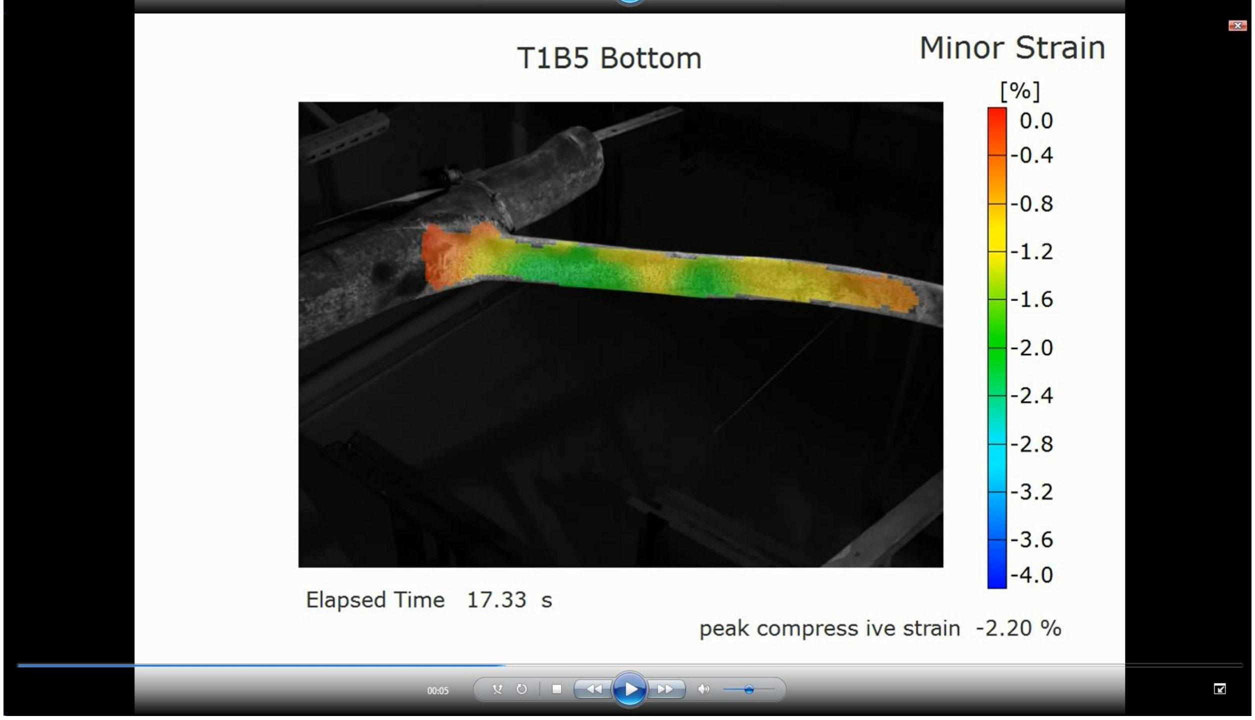
APPENDIX 2 SEQUENCES OF IMAGES AS BRANCH IS LOADED TO FAILURE



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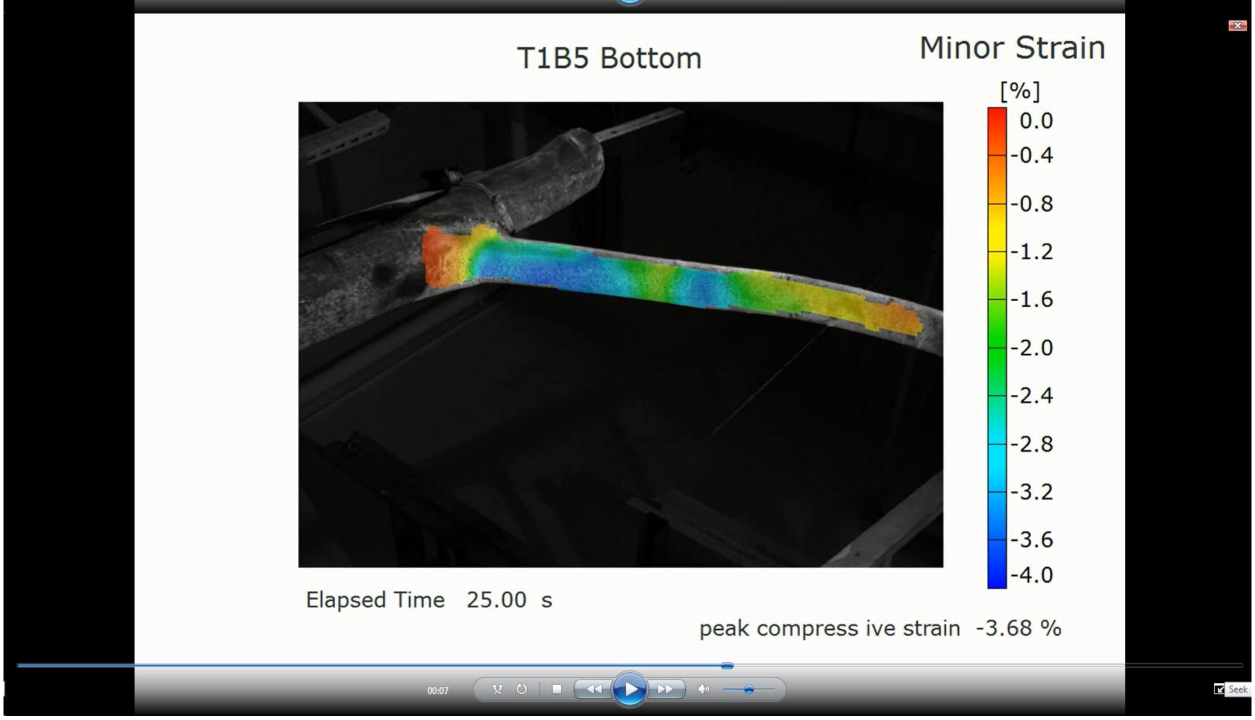

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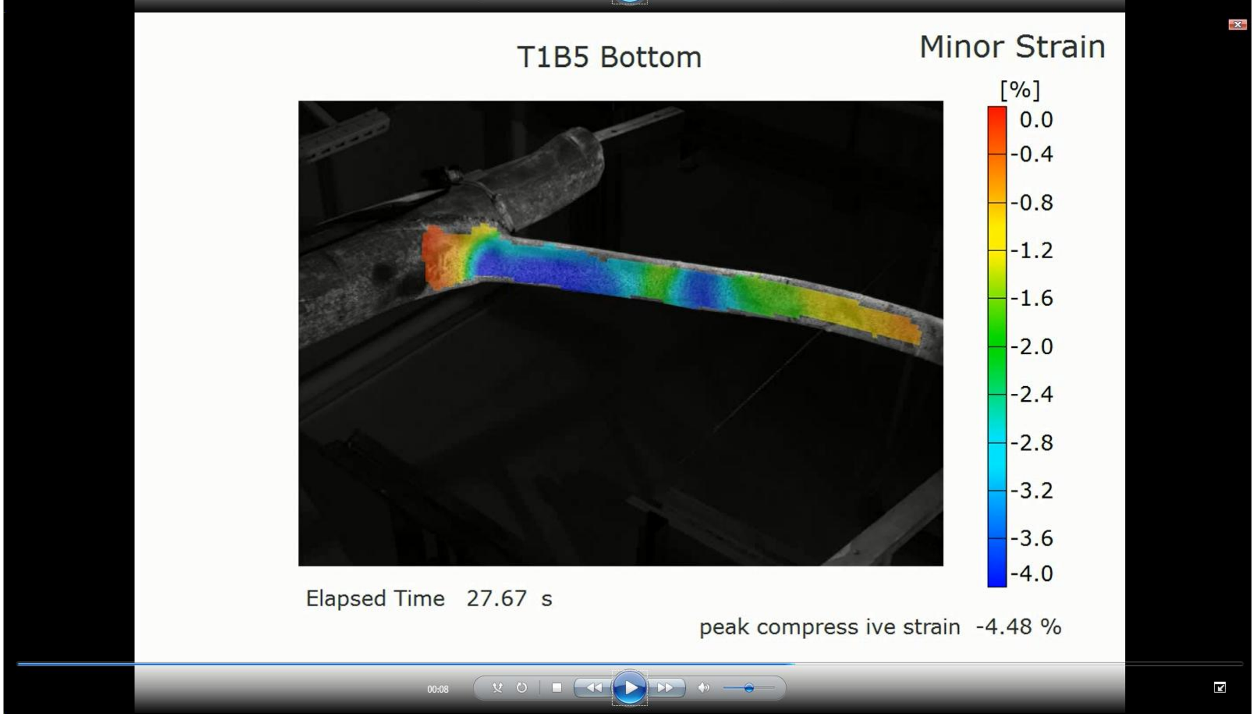

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