Effects of Uniaxial Tensile Strain on Moth Wings Through Digital Image Correlation

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Abstract

The aim of my research is to investigate the material properties of Hawkmoth wings, specifically the measurement of Young's Modulus and the Poisson's ratio for bulk pieces of the wing. This was achieved by raising moths, slicing their wings into strips, and measuring the stress and strains during uniaxial tensile testing. Digital image correlation was used to compute the deformation of the wing under constant strain with greater accuracy. While others have investigated small portions of insect wings, a bulk method is novel. Preliminary results possess attributes similar to the outcomes of previous studies, along with the presence of relaxation. This presentation will discuss my findings about Poisson's ratio of Hummingbird Hawkmoth wings.

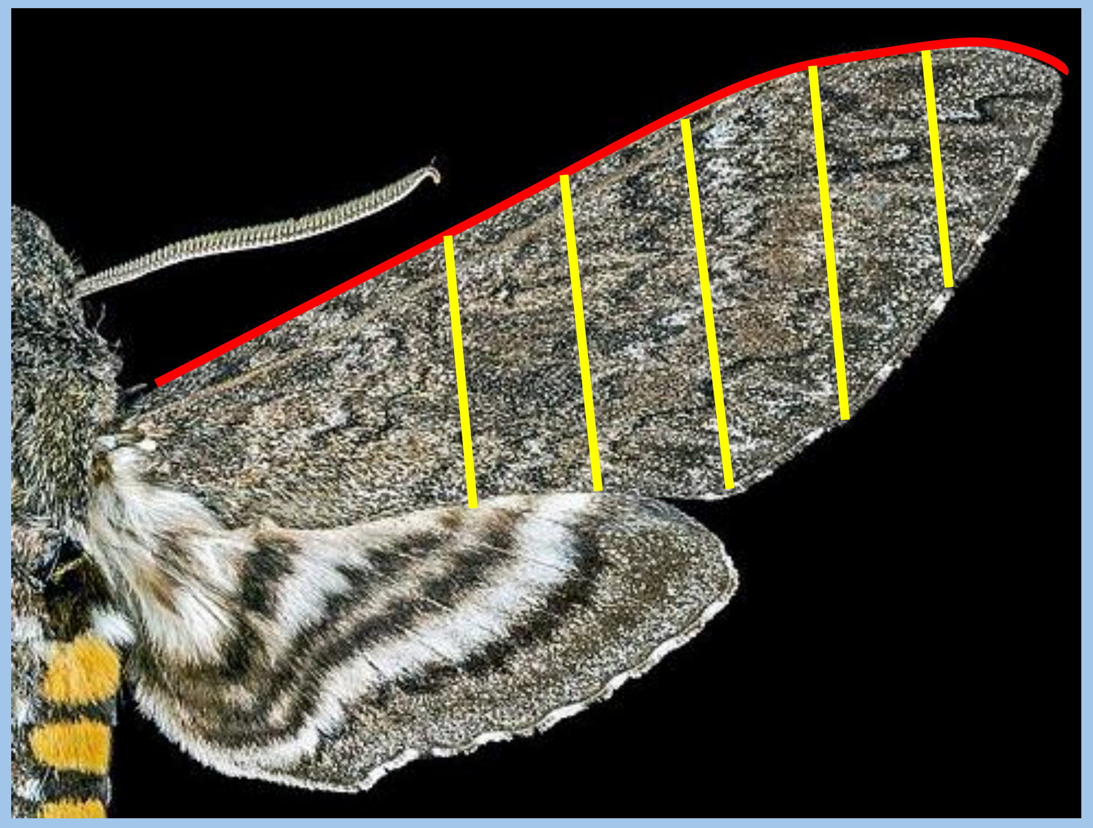

Figure 1: A view of a Hummingbird Hawkmoth's right wing. The red line shows the spanwise direction of the wing. For this experiment we cut the wing chordwise (in yellow) and measured the strain in that direction.

Figure 6: A close view of Hummingbird Hawkmoth wing prior to being cut.

References

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2. D. Lecompte, A. Smiths, Sven Bossuyt, H. Sol, J. Vantomme, D. Van Hemelrijck, A.M. Habraken. Quality Assessment of Speckle Patterns for Digital Image Correlation, Optics and Lasers in Engineering 44, 2006

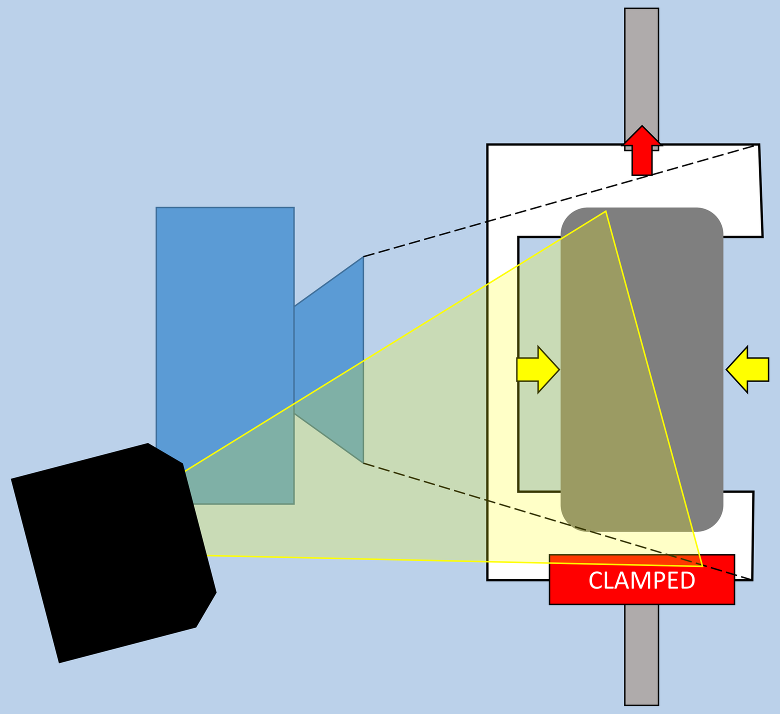
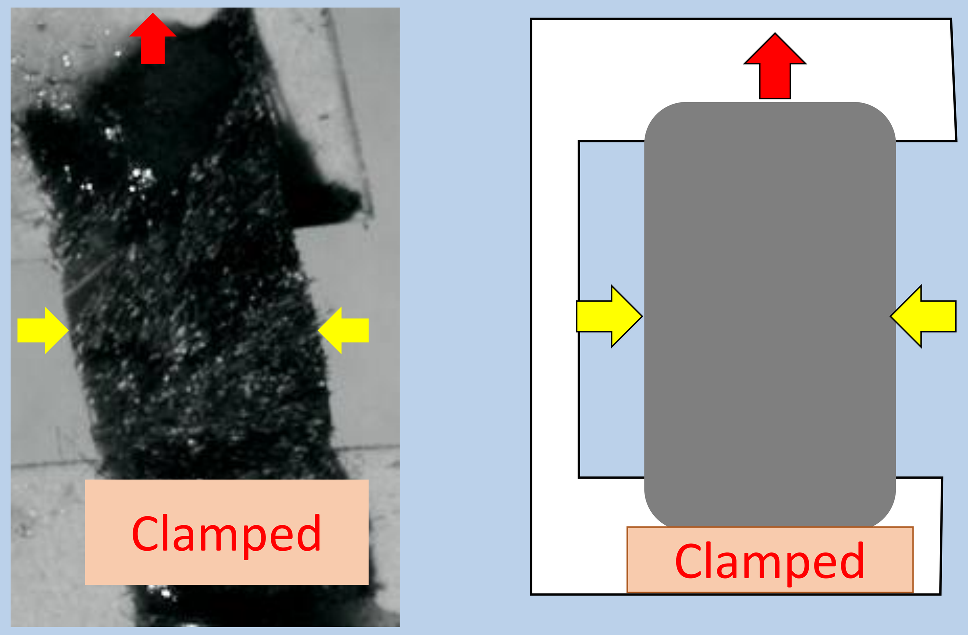


Figure 2 [left]: A graphic representing the setup used to measure the strain on the insect wing. The wing [grey] is set in the tensile tester with the camera [blue] and light [black] setup to view the entire motion of the wing.

Figure 3 [right]: Figure 3.a is a sample wing clamped into the tensile tester. The red arrows in Figure 3 show the direction the wing is being pulled in. They also show the direction of the axial strain while the yellow arrows show the transverse strain.

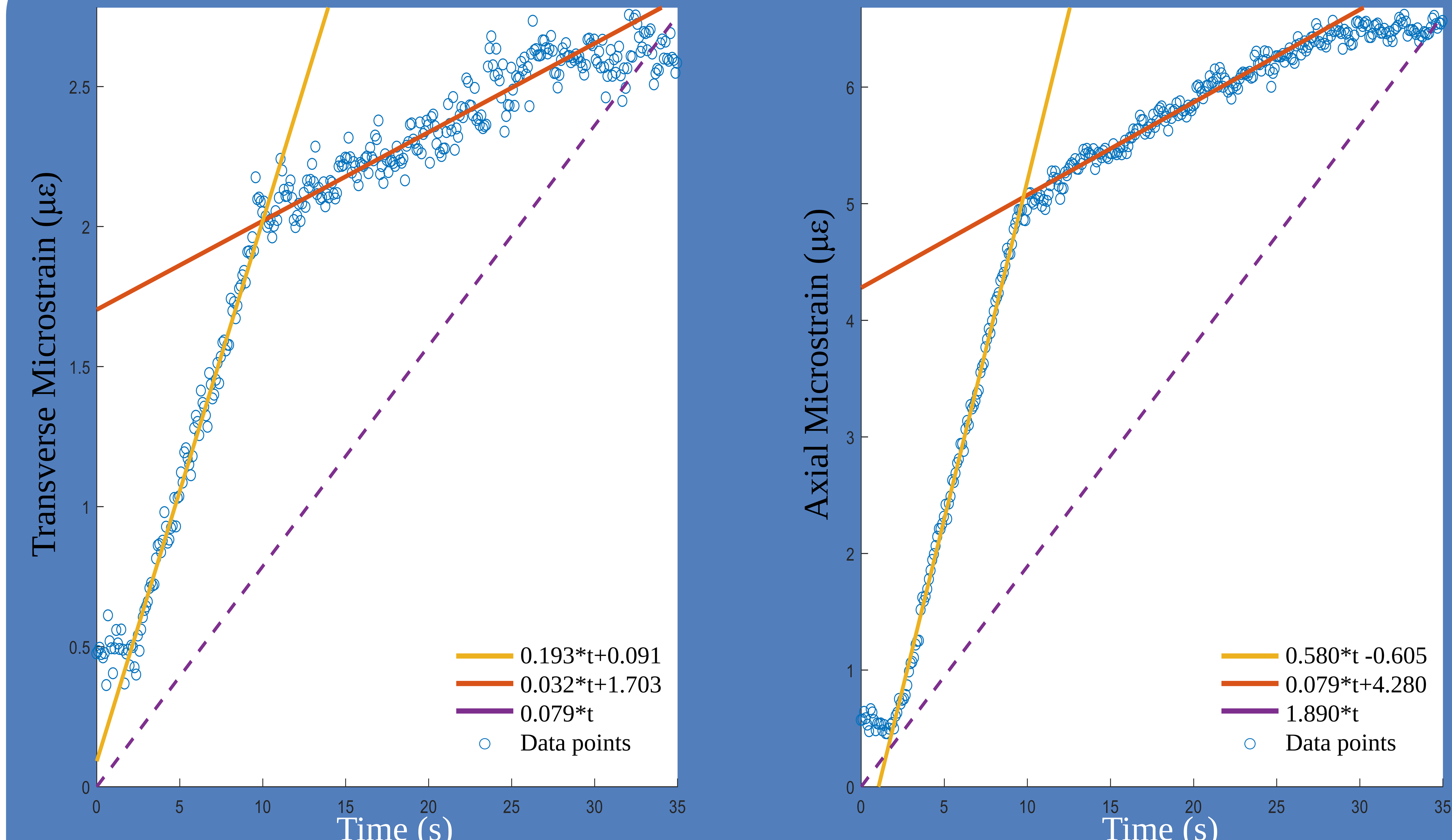


(a) (b)

Goals

1. Experimentally determine the Poisson's ratio of Hummingbird Hawkmoths.
2. Address irregularities between the expected and measure output. Infer the cause of the difference.

Figure 4: A picture of a wing cut chordwise. Figure 5 was found using the result of strip number 2.



(a) (b)

Figure 5: The graphs show the strain reaction of the insect wing while in the tensile tester. Figure 5.a shows the transverse strain and Figure 5.b shows the axial strain on the wing. The solid lines show the linear regression of strain over time, while the dotted line is an estimate of the expected result. Figure 5 suggests that the wings experience through hardening when at large at large strain values.

Results

The plots from Figure 5 show the relationship between the strains acting on the moth wings over time. Using linear approximation to get the rate of change of the axial and transverse strains, the Poisson's ratio can be approximated by:

$$\nu = \frac{d\varepsilon_{trans}}{d\varepsilon_{axial}} = \frac{d\varepsilon_{trans}}{dt} \div \frac{d\varepsilon_{axial}}{dt}$$

Since the material goes through hardening, we expect different material properties before and after the wing hardens. From this and the data collected we infer that:

$$\nu_{prior} \approx 0.296$$
$$\nu_{post} \approx 0.352$$
$$\varepsilon_{hardening} \approx 5.95\mu\varepsilon$$

Future Plans

More tests are required to reduce the uncertainty in out finding. While the force acting on the wing can be found, we did not have access to an accurate measurement of the cross-sectional area. Without the cross-sectional area, the stress on the wing cannot be measured and therefore the Modulus of Elasticity cannot be found.