UNIVERSITY OF Southampton

Inside a Feather

Laminar Layup Varies Around and Along Bird Feather Shafts

Since feathered flight developed more than 150 million years ago, the central shaft of a bird feather has evolved under selection pressures to become light, stiff, and strong. As a result, the shaft has become a complex, fibre-reinforced biocomposite beam.

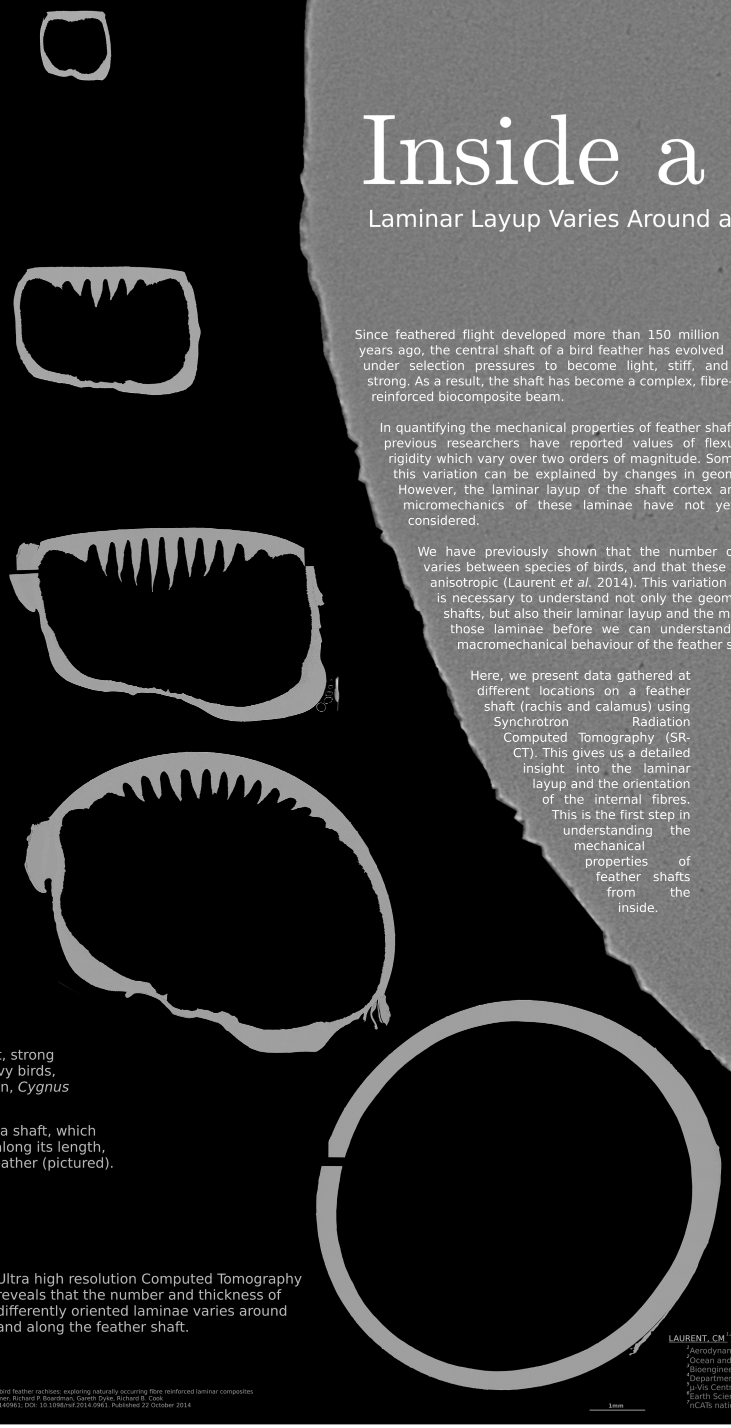
In quantifying the mechanical properties of feather shafts, previous researchers have reported values of flexural rigidity which vary over two orders of magnitude. Some of this variation can be explained by changes in geometry. However, the laminar layup of the shaft cortex and the micromechanics of these laminae have not yet been considered.

We have previously shown that the number of laminae varies between species of birds, and that these laminae are anisotropic (Laurent *et al.* 2014). This variation means that it is necessary to understand not only the geometry of feather shafts, but also their laminar layup and the micromechanics of those laminae before we can understand and predict the macromechanical behaviour of the feather shaft.

Here, we present data gathered at different locations on a feather shaft (rachis and calamus) using Synchrotron Radiation Computed Tomography (SR-CT). This gives us a detailed insight into the laminar layup and the orientation of the internal fibres. This is the first step in understanding the mechanical properties of feather shafts from the inside.

Flight feathers are light, strong and stiff and allow heavy birds, such as a whooper swan, *Cygnus cygnus*, to fly.

Each flight feather has a shaft, which changes in geometry along its length, like the second flight feather (pictured).



Ultra high resolution Computed Tomography reveals that the number and thickness of differently oriented laminae varies around and along the feather shaft.

Method

The Swiss Light Source (SLS), at the Paul Scherrer Institute (Switzerland), is a third-generation synchrotron light source. It provides a high-brightness photon beam which enables CT scanning at resolutions three orders of magnitude higher than a typical hospital-based scanner, with scan times as short as six minutes. With these scans, we capture the three-dimensional void orientation in rachis material. Using transmission electron microscopy, these voids were found to be aligned with the internal fibres.

Samples (L = 5 mm) were removed from the leading flight feather of a Whooper Swan (*Cygnus cygnus*) at 10, 30, 50, 70, and 90% of the shaft length and scanned. Overlapping regions of interest were stitched together and the whole sample was reconstructed with voxel dimensions of 325 nm. The largest sample (10%) required 42 individual scans and the smallest (90%) only six. Scans were stitched together using a Fourier-shift algorithm where possible, or with the 'MosaicJ' tool in ImageJ/Fiji.

Results & Conclusion

Our SR-CT scans reveal geometry of the shaft changing along the length of the feather. Looking more closely they show how the number, orientation, and thickness of laminae vary within the shaft. Therefore, our results show that laminar layup varies around, and along, a bird feather shaft.

These variations in geometry and laminae influences the rachis mechanics. Next, to fully understand the implication for the feather mechanics, we will determine the modulus of individual laminae.

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Approximate scale indicated by thumbnail

Reference:
Nanomechanical properties of bird feather rachises: exploring naturally occurring fibre reinforced laminar composites
Christian M. Laurent, Colin Palmer, Richard P. Boardman, Gareth Dyke, Richard B. Cook
J. R. Soc. Interface 2014 11 20140961; DOI: 10.1098/rsif.2014.0961. Published 22 October 2014

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