Push or Pull, How Does Silk Flow?

J. Sparkes[1]

[1]University of Sheffield, Sheffield, UK

Abstract

Silk is one of the longest used and most recognizable textiles that we, as a society, use regularly. We see it as a luxury good, worn as an indicator of success and value. However, despite mankind having domesticated and farmed silkworms for millennia, we still know relatively little about the manufacturing process which converts the liquid silk into the fibers we are so familiar with. Commercial silk is most commonly harvested from the cocoons of the Chinese silkworm Bombyx mori, which is farmed on an industrial scale. However, there are many other arthropods, including insects, myriapods and arachnids, which produce silks. Of these, it is the dragline silk produced by orb-weaving spiders which has received the most attention due to its high strength and toughness, both of which are desirable properties, especially in a biodegradable fiber which can be produced in ambient conditions [1].

Increased understanding of the processing conditions which silk producers employ will help in our search for tailor-made bio-sourced fibers. In nature, silk is stored as a liquid which can be converted on demand into a fiber which can possess a wide range of material properties depending on its intended use. It has been found that silks undergo this phase transition as a result of reduced levels of hydration (greater concentration), a reduction in pH along the gland, and through shear and extensional flows created by the geometry of the duct in which it travels.

Previous research has identified shear as the primary source of fiber formation in the gland [2], along with high resolution images of its shape and structure. Combining these with the increasingly accurate rheological data from the Natural Materials Group [3] allows us to explore these structures and determine relationships between the rheological, geometric and mechanical properties in greater detail than ever before [4-7].

The use of parametric analysis in COMSOL Multiphysics® software and LiveLink™ for MATLAB® will allow us to explore Ridley's statement that "evolutionary systems are only energetically optimized as they need to be, not necessarily can be" [8] by comparing the differences between different sets of published rheological data for both spiders and silkworms against different duct geometries, with the eventual aim of producing a series of dies optimized for the creation of fibers with radically or subtly distinct properties. In doing so, we take one more step down the path to producing synthetic silk fibers with properties tailored to specific applications.

Reference

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Figures used in the abstract

Figure 1: Common silk producers and their silks, Spiders (L), and silkworms (R).