Mechanical Properties of Spider Silk

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Overview

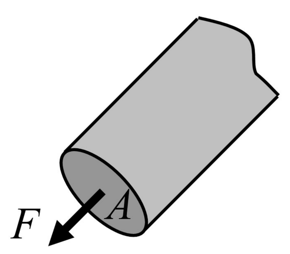
We examine various mechanical properties of spider silk. Spider silk is used to hold deuterium and tritium fusion targets in place at LLE. Our investigations should eventually determine the extent these mechanical properties change after the silk is exposed to high levels of beta radiation. The results should indicate whether using spider silk to hold tritium targets in place is feasible given tritium's highly radioactive nature.

Mechanical Properties

Stress:

$$\sigma = \frac{F}{A}$$

$$A = \frac{\pi D^2}{4}$$

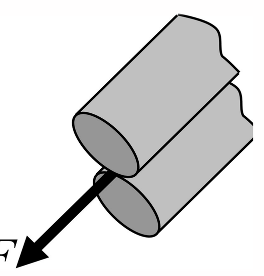


Strain (ε): normalized elongation
δ = change in length of the sample
L = original length of sample

$$\varepsilon = \frac{\delta}{L}$$

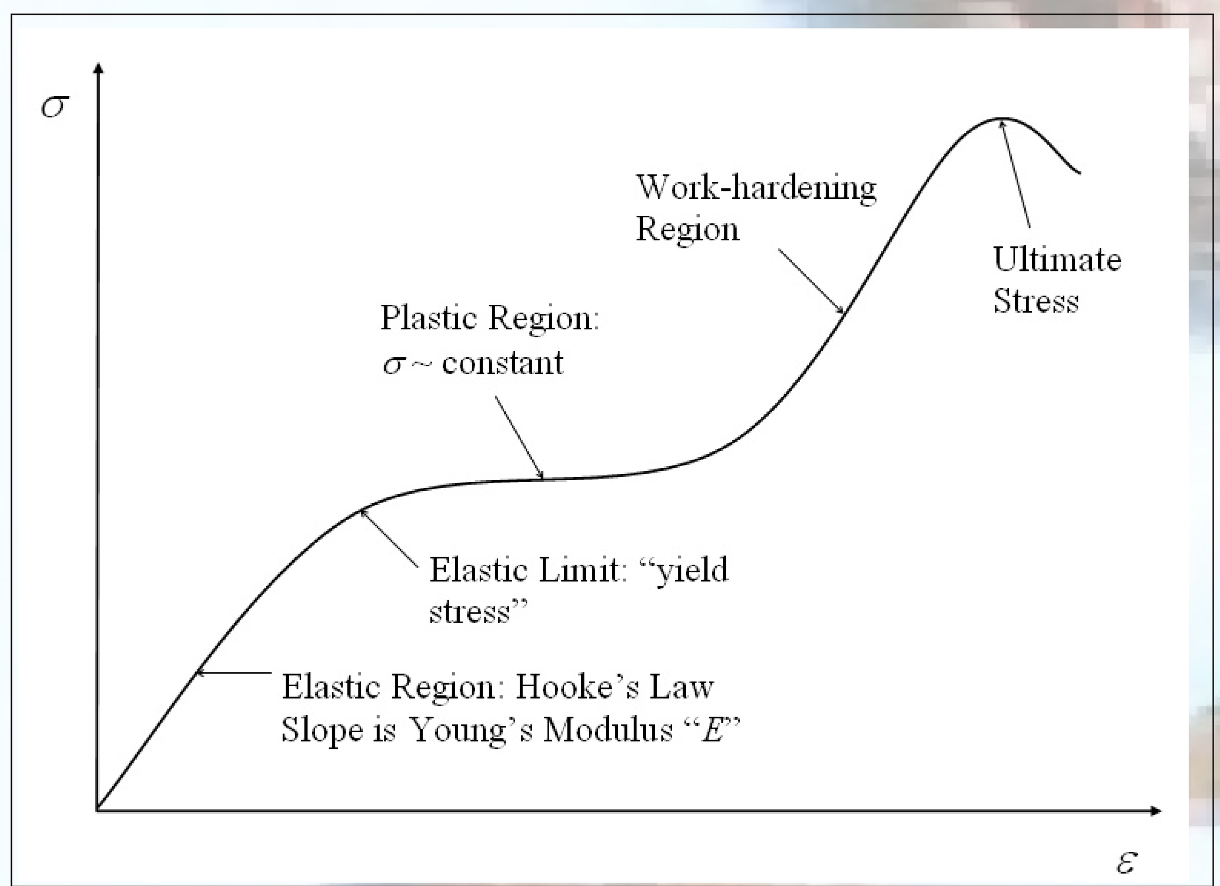
For two strands:

$$\sigma = \frac{2F}{\pi D^2}$$



Toughness:

$$\int_0^{\varepsilon_{max}} \sigma(\varepsilon)d\varepsilon = \frac{1}{AL}\int_0^{L} F(\varepsilon)dx$$



Stress-strain diagram for a typical ductile material.

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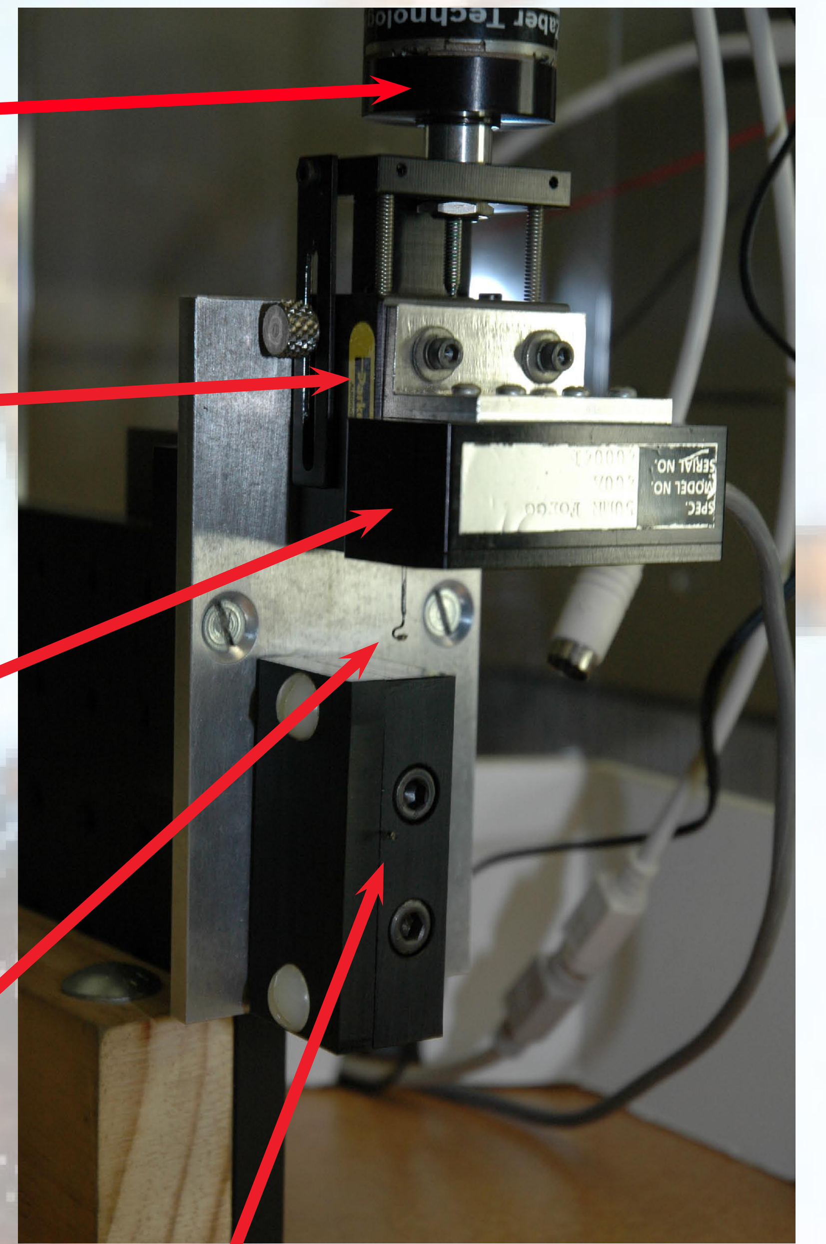
Apparatus



Linear Actuator
Controls the strain of the sample (computer controlled).

Translation Stage
Couples the linear actuator and the force transducer.

Force Transducer
Creates a voltage proportional to the tensile force in the silk.

Mounting Hook
Connects the sample to the force transducer.

Lower Pin
Holds the fixed lower end of the silk.

Our Spiders & Their Silk

Spider Care:

Each spider has its own petri dish to live in supplied with a wet sponge. Each is fed once a week.

Species:

Steatoda Bipunctuata

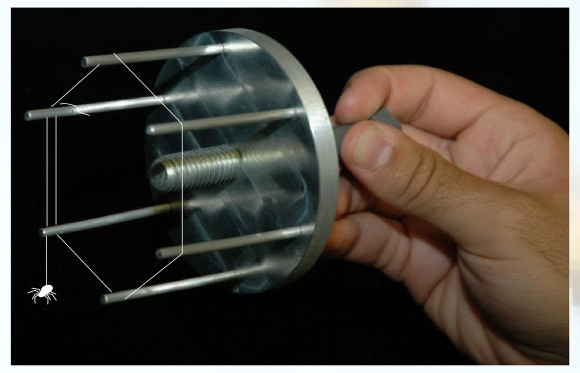
Steatoda Triangulosa

The Silk:

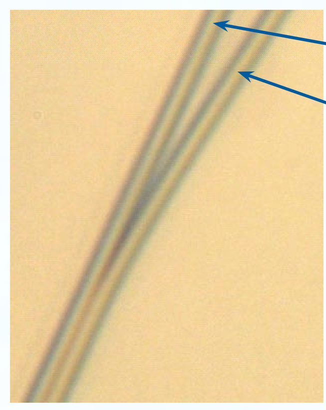
Spiders manufacture 7 distinct types of silk. We use "dragline," typically used by spiders as a safety line when they fall.

The "dragline" consists of a pair of stands that the spider drops which are about 1 μm in diameter.

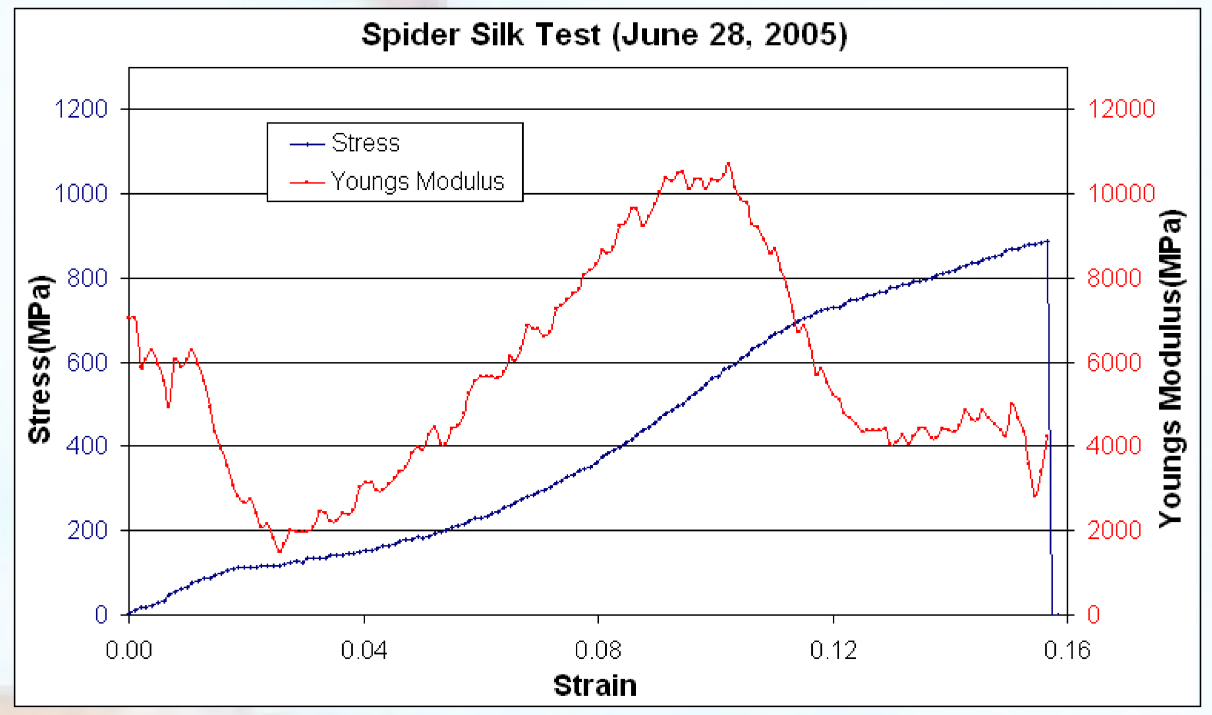
Harvesting the Silk:



The spider is dropped from the wheel and the wheel is spun to collect the silk

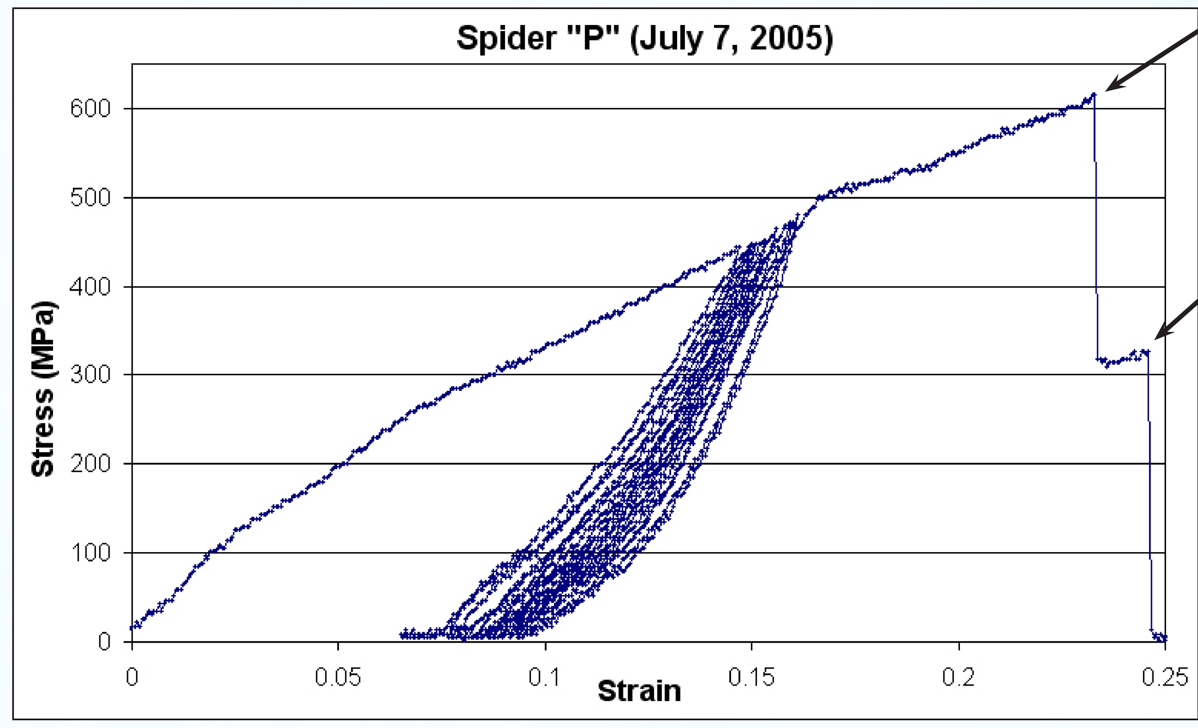


Results



In this plot, the silk appears to consist of one strand due to its low ultimate stress and lack of two clearly defined breaks. Young's Modulus is the derivative of the stress strain graph.

Ultimate Stress: 890 MPa
Force to break: 1.1 mN
Toughness: 66 MJ/m^3



In this experiment, the strain oscillates between two values. Hysteresis is evident. Evidence of a second strand is also apparent.

Future Work

Irradiation
Compare results of irradiated silk to unradiated silk.

Careful measurement of demensions
A more accurate measurement of the length and diameter of the silk are needed.

Handling
A more efficient mounting procedure to prevent pre-stressing before testing.

Conditions
How humidity, temperature, pressure and exposure time affect the results.