Spider’s web

Condition of the problem:

Spider’s thread looks like a string of pearls. What is the reason for this? Make experiments to investigate the relevant parameters.
Spider's web like beads.

- Spider’s web looks like beads itself if watch on it through the microscope.

- Web is similar to thread of pearls with drops of dew on it.
Web's structure.

Web through the microscope.

Every system tends to the state with minimum energy.

$$E_s = \sigma S$$

Drops forming from a liquid cylinder.
Theoretical model.

\[ r(x,t) = r_0 + y(x,t) \]

\[ y(x,t) = A(t) \cos \left( \frac{2\pi}{\lambda} x \right) = ae^{\alpha t} \cos \left( \frac{2\pi}{\lambda} x \right) \]

Where
- \( t \)-time;
- \( a \)-the initial amplitude;
- \( \alpha \)-coefficient, which characterize damping or growth of the wave.

\[ \rho \frac{\partial^2 y}{\partial t^2} = -k \frac{\Delta p}{\lambda} \]

\( \rho \)-density;
\( \partial^2 y/\partial t^2 \)-acceleration of unit volume

\[ F = -\partial p / \partial r; \]
\[ \partial p / \partial r = k \Delta p / \lambda \]

\( \Delta p \)-pressure difference.
\[ P - P_a = \sigma \left( \frac{1}{R_1} + \frac{1}{R_2} \right) \]

- \( P_a \) - the atmospheric pressure;
- \( \sigma \) - surface tension coefficient;
- \( R_1 \) and \( R_2 \) - main radiiuses of curvature.

\[
\frac{1}{R_1} = \frac{1}{r(0,t)} = \frac{1}{r_0 + A} \approx \frac{1}{r_0} \left( 1 - \frac{A}{r_0} \right)
\]
Radius of curvature.

\[ \Delta r = r(0,t) - r(x,t) = A \left( 1 - \cos \frac{2\pi}{\lambda} x \right) \]

\[ \cos \frac{2\pi}{\lambda} x \approx 1 - \left( \frac{2\pi}{\lambda} \right)^2 x^2 / 2 \]

\[ \Delta r = A \left( \frac{2\pi}{\lambda} \right)^2 x^2 / 2 \]

From triangle ABD it follows:

\[ 2R_2 \Delta r = x^2 \]
Condition of instability.

\[ \Delta p = P - P_0 = \sigma A \left( \left( \frac{2\pi}{\lambda} \right)^2 - \frac{1}{r_0^2} \right) \]  - change of pressure.

\[ \partial^2 y / \partial t^2 = \alpha^2 A \]

\[ \alpha^2 = \frac{k\sigma}{\rho r_0^2 \lambda} \left( 1 - \left( \frac{2\pi r_0}{\lambda} \right)^2 \right) \]

Condition of instability of liquid cylinder: \[ \lambda > 2\pi r_0 \]

Wavelength with the highest growth speed:

\[ \lambda_{\text{max}} = 2\sqrt{3\pi r_0} \]
Drops sizes.

\[ R_{\text{Drop}} = \left( \frac{3}{4} r_0^2 \lambda_{\text{max}} \right)^{1/3} \]

\[ R_D = \frac{\lambda_{\text{max}}}{2} \left( \frac{1}{2\pi^2} \right)^{1/3} \]

Theory: 

Nature sizes:
Experimental model.

When length of the cylinder is more than three its diameters it begins disintegrate on two drops.

A hair with oil
Influence of different parameters.

Drops of nitrolaquequer on a hair

\[ \lambda_{\text{max}} = 2\sqrt{3\pi r_0} \]

More viscous liquid \( r_{01} > r_{02} \)

Less viscous liquid
Threads with different diameters.

Fishing-line and pitch
The dependence of drop height on thread diameter.
The dependence of the distance between drops on thread diameter.
The process of drop forming.
Condensation begins from the blobs of spider’s web, which serve as the centres of condensation.

\[ \varphi = \frac{p_{w.v.}}{p_s} \cdot 100\% \]
Dewfall.
Flashes on the drop.
Conclusion.

- Simularity between web structure and beads.
- Theoretical model.
- Experimental model.
- Drop sizes. Influence of different parameters
- The process of drop forming
- Condensation and dewfall
- Flashes on the drops.