Wrinkling of a floating sheet - Analysis

Teachers' programme on Patterns in Nature

We'll start with the data you collected on the number (N) and length (L) of wrinkles that you collected. The goal is to try and think through how these descriptors of a pattern (dependent variables) are controlled by what you did in the experiment (independent variables).

One idea that we'll use is that in any meaningful equation, units should match on both sides of an equation,

Example: F=ma   implies that [Force] = [Mass] x [Length]/[Time]^2

<u>Dependence on drop size (a) and thickness (t)</u>

We start with the data pooled from all groups on a google spreadsheet (http://tinyurl.com/wrinkle2017).

Plot N vs a for three thicknesses on a linear plot. Answer the following questions:

I. Does N decrease/increase with a?

II. Linear? Less than linear? More than linear?

III. Next, for a given value of a, does N decrease/increase with t?

IV. Linear? Less than linear? More than linear?

Instead of plotting N against a, let's try to plot some combination of N and t on the y-axis against a on the x-axis.

If you were to use N/t^{α} as new y-variable (where a is some unknown power), based on your answers above, should α be positive or negative? Should it be bigger or smaller than 1?

Try to get "data collapse" of all plots on a single curve, by varying α. This method is a central tool to find the dependence of a physical observable on a single parameter, from a large data set. This allows you to figure out the dependence of N on t.

Now try to find the dependence on N on a. You may try to repeat the previous procedure (i.e. plot Na^{β} and get data collapse by varying β).

[A different and efficient way to do this, is to re-plot the original plots (of N(a)) on log-log scale. In such a log-log plotting, the various plots should appear approximately as parallel linear functions. You can obtain β simply by measuring the slope.]

<u>Dependence on other variables</u>

Now recall our discussion on the nature of physical laws. Let's start by recalling that N is a pure number, with no units! Both drop size (a) and thickness (t) have units of length. Unless a and b are the same number, $N = t^{\alpha}/a^{\beta}$ cannot be a valid equation.

This means there must be another physical quantity with units of length that participates in this law. Physically, some possibilities are the elasticity of the sheet , the surface tension of the water, or the gravity of water. Using the table below, suggest two possible candidates for a physically-meaningful physical law for N.

Physical constant	**symbol**	**Units**
Elastic (Young) modulus	E	[Energy]/[Length]^3
Surface tension	γ	[Energy]/[Length]^2
Gravitational force	ρ g	[Energy]/[Length]^4

Is there an experiment that can be done to find the correct law?