Investigating the Fracturing of Raw Spaghetti

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1 Introduction

1.1 Purpose

To understand how the separation of the applied forces on the spaghetti affect the length of the secondary fracture.

1.2 Hypothesis/Prediction

I predict that as the distance between the two forces decreases, the length of the broken spaghetti pieces will decrease, as there will be less space for a cascading fracture to take place.

1.3 Variables

Independent Variable

- Width between forces [cm]

Dependent Variables

- Length of broken spaghetti pieces [cm]

Controlled Variables

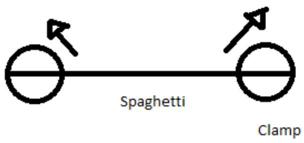
- Length of starting spaghetti [25.0 cm]
- Width of starting spaghetti [0.2 cm]
- Mass of starting spaghetti [5.4 g]

2 Materials

- Spaghetti ·20
- Rotatable clamps ·2
- Ruler ·1
- Scale ·1

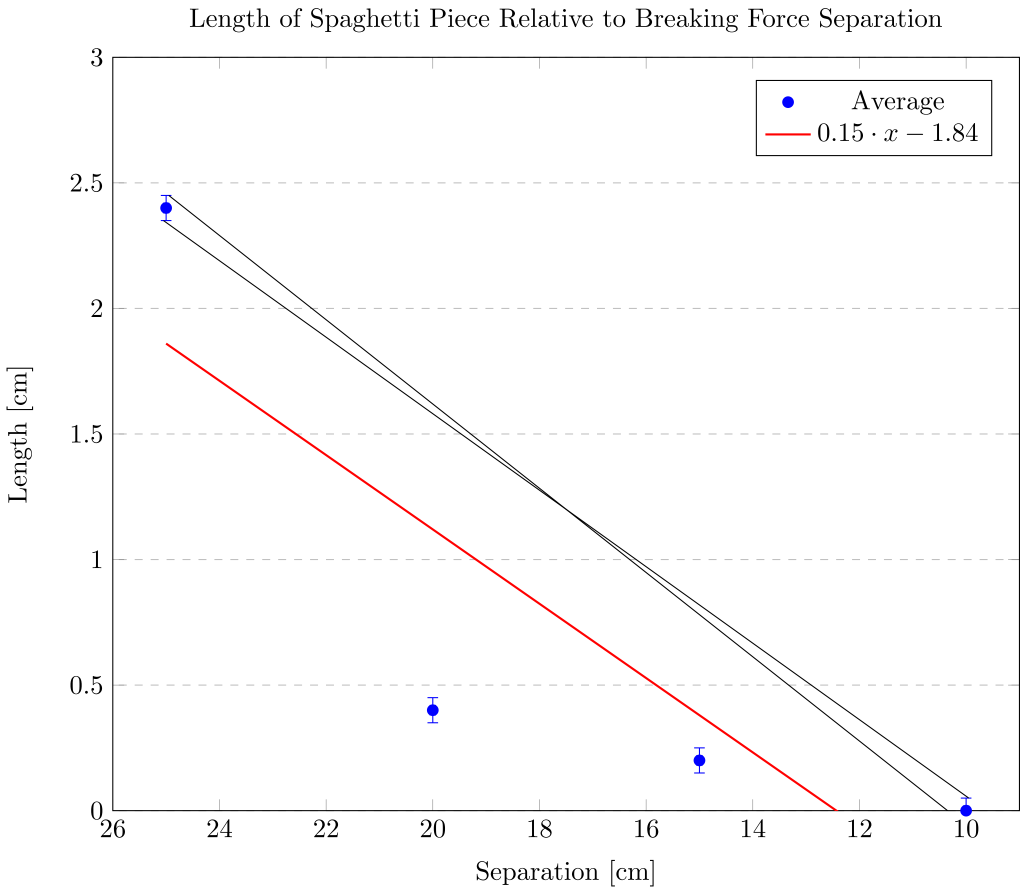
3 Procedure

1. (CONTROL) Measure length of spaghetti
2. (CONTROL) Measure width of spaghetti
3. (CONTROL) Measure mass of spaghetti
4. Pick a spaghetti, check it is within margin of error (0.05 cm)
5. Measure distance between clamps (25, 20, 15, and 10 cm)
6. Clamp spaghetti
7. Turn clamps at the same speed until spaghetti breaks
8. Measure length of broken spaghetti pieces, if any (else record 0.0 cm)
9. Repeat steps 4-8 as necessary for data collection
10. Repeat step 9 with remaining distances



4 Data

Separation cm	Trial 1 cm	Trial 2 cm	Trial 3 cm	Trial 4 cm	Trial 5 cm	Average cm
25.0	2.3±0.05	2.4±0.05	2.4±0.05	2.5±0.05	2.2±0.05	2.4±0.05
20.0	0.0±0.05	0.0±0.05	1.0±0.05	0.9±0.05	0.0±0.05	0.4±0.05
15.0	0.0±0.05	0.0±0.05	0.0±0.05	0.4±0.05	0.5±0.05	0.2±0.05
10.0	0.0±0.05	0.0±0.05	0.0±0.05	0.0±0.05	0.0±0.05	0.0±0.05



5 Explanations

5.1 Uncertainty

There are uncertainty bars for both x and y axes, though they are difficult to see on the x axis due to scaling issues. Uncertainty was assumed to be 0.05 cm, as the ruler used could only measure within the nearest 0.1 cm, meaning that the 0.1 cm region that was 50% offset from the ruler would be least certain.

5.2 Intercepts

There is only one intercept on the graph, and that is when, at a separation of 10.0 cm, the spaghetti does not fracture into any extra pieces during any of the five trials.

5.3 Slope

The slope is positive (0.15), meaning that as the width between the two clamps increases, the length of the secondary broken spaghetti piece will also increase.

6 Calculations

6.1 Average

$$\langle x_i^* \rangle \tag{1}$$

$$\frac{\sum_i x_i}{i} \tag{2}$$

$$\frac{x_1 + x_2 + ... + x_{i-1} + x_i}{i} \tag{3}$$

6.2 Error and Minimization for Line of Best Fit

Error was calculated using sum squared error, which is defined as follows:

$$E = \sum_{i=1}^{n} (y_i - f(x_i))^2 \tag{4}$$

While a program carried out the minimization of the function, the basic premise of minimization is to "follow the gradient," so to speak. The program follows the gradient

$$E' = \frac{\partial}{\partial x}(\sum_{i=1}^{n} (y_i - f(x_i))^2) \tag{5}$$

similar to Euler's method for solving differential equations. Minimizing the function is simply following the "negative" slope to the local minima of the function.

7 Conclusion

My hypothesis, that the length of the secondary break will shorten as the separation of the applied forces on the spaghetti was reduced, was supported by the data. When the separation was 25.0 cm, the secondary break averaged a length of 2.4 cm. At 20.0 cm, the average dropped to 0.4 cm. 15.0 cm had an average of 0.2 cm, and, the smallest separation, 10.0 cm, produced an average of 0.0 cm, meaning that no secondary pieces were produced from the breaking of the spaghetti through the five trials. This makes sense, as when the distance between the two clamps was decreased, there was less "spaghetti" available for a cascading fracture to take place. A cascading fracture, in this case, is the secondary fracturing of the spaghetti due to regions (namely the centre region) of the spaghetti straightening before other regions (like the bases). In regards to the data, however, I believe there is too much random error at play to make an outright statement of the validity of my hypothesis. Spaghetti has too much inherent randomness to make it a reliable object of measurement. A spaghetti could have microscopic weaknesses that predispose it to breaking from certain locations: perhaps another spaghetti was slightly more dense; it would have been impossible to tell with my measuring devices. Additionally, as I was the one turning the clamps, I was introducing error into the measurements; humans are not precise. However, because the data shows such an overwhelming trend in support of my hypothesis, I believe I can claim that my hypothesis is valid.

The design of the investigation was not incredible by any stretch of the mind, but given that it was quite simple, the implementation, I believe, was up-to-par with the standards I had in mind. That said, I was not impressed by the error accrued throughout the investigation. As I said before, the spaghetti was a central source of randomness throughout the investigation. A particular with my investigation, the clamps, also introduced randomness, but this was the product of a compromise instead of ignorance. As I was investigating the secondary breakage of spaghetti (around the centre), I wanted to make sure that I was avoiding contact with the centre region of the spaghetti at the time of breakage. As a result, I had to resort to rotating clamps as a compromise, as even though I still control their movement, I felt that they would provide a more consistent torque than my hands would. The error introduced by both sources, in the end, were mostly random; the results could essentially have gone either way.

One improvement that comes to mind is replacing the spaghetti with thin plastic sticks; the material would be more uniform (mass, dimensions, elasticity), and would thus introduce less random error into test results. However, this would undoubtedly be more expensive, so whether or not it would be feasible is unknown.