Modelling Saffman-Taylor-based Dendritic Structures

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Motivation:

- The formation of Dendritic structures created within a lifted Hele-Shaw cell is guided by Saffman-Taylor instability, which results in each dendrite being unique and unreproducible.
- The distinctiveness of each dendrite points to applications in counterfeit protection as unclonable identification tags.
- While the specific pattern is not predictable, general structural attributes like the number of branches should be predictable. Predictability in overall structure can help to reconstruct damaged dendrites in identification applications.
- Current scanning systems can be limited by the size and density of the dendrites branches, so being able to determine those attributes would be hugely beneficial.
- Rough mathematical models have been developed looking at Newtonian systems, but if they can be applied to other fluid systems, they could be used to guide materials selection.

Figure 1: Magnified image of a dendrite. Actual diameter is 6.28 mm.

Dendritic Structures:

- Dendrites are formed by compressing a viscous fluid between two parallel plates and then separating the plates. Air penetrates from the edge into the viscous fluid forming fingers.
- The number of these fingers decreases with distance from the edge and is dependent on the properties of the viscous fluid, specifically viscosity and surface tension.
- For this project, the dendrites were made with acrylic paint on a clear polyester substrate.

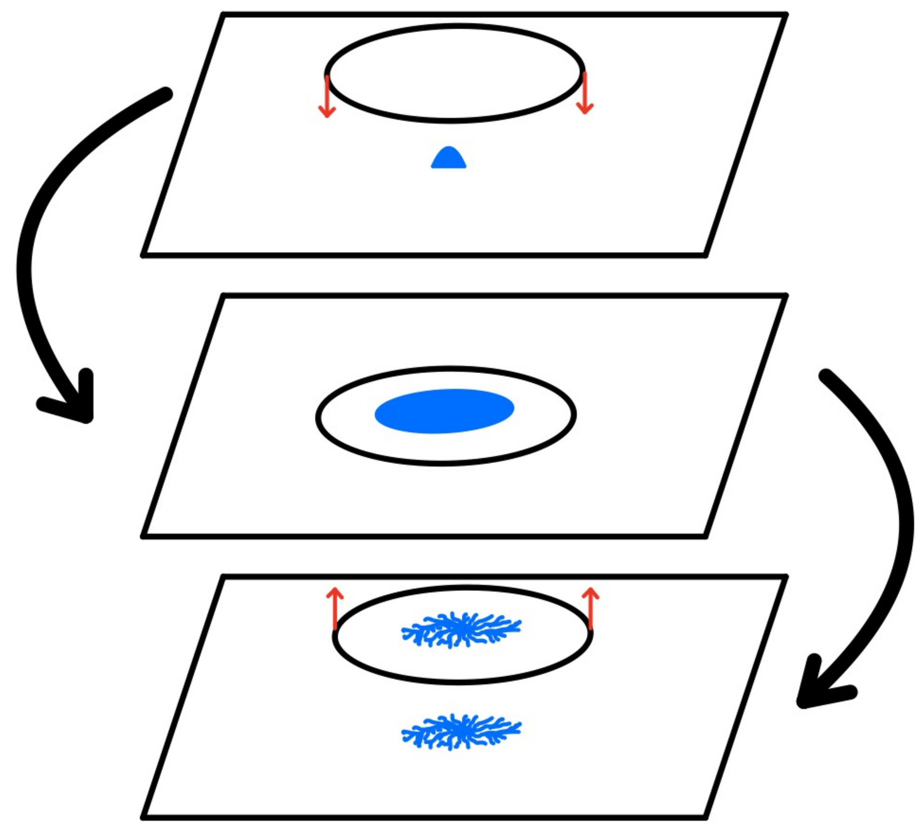

Figure 2: Basic dendrite production procedure in a lifted Hele-Shaw cell.

Research Methods:

- Using measured viscosity values and representative surface tension data for acrylic on polyester, structural information was estimated using the model proposed by Nase, Derks, and Lindner.
- Nine example dendrites were created with identical materials under consistent conditions.
- The number of fingers at certain positions were counted and compared to the estimation.

Findings and Progress thus Far:

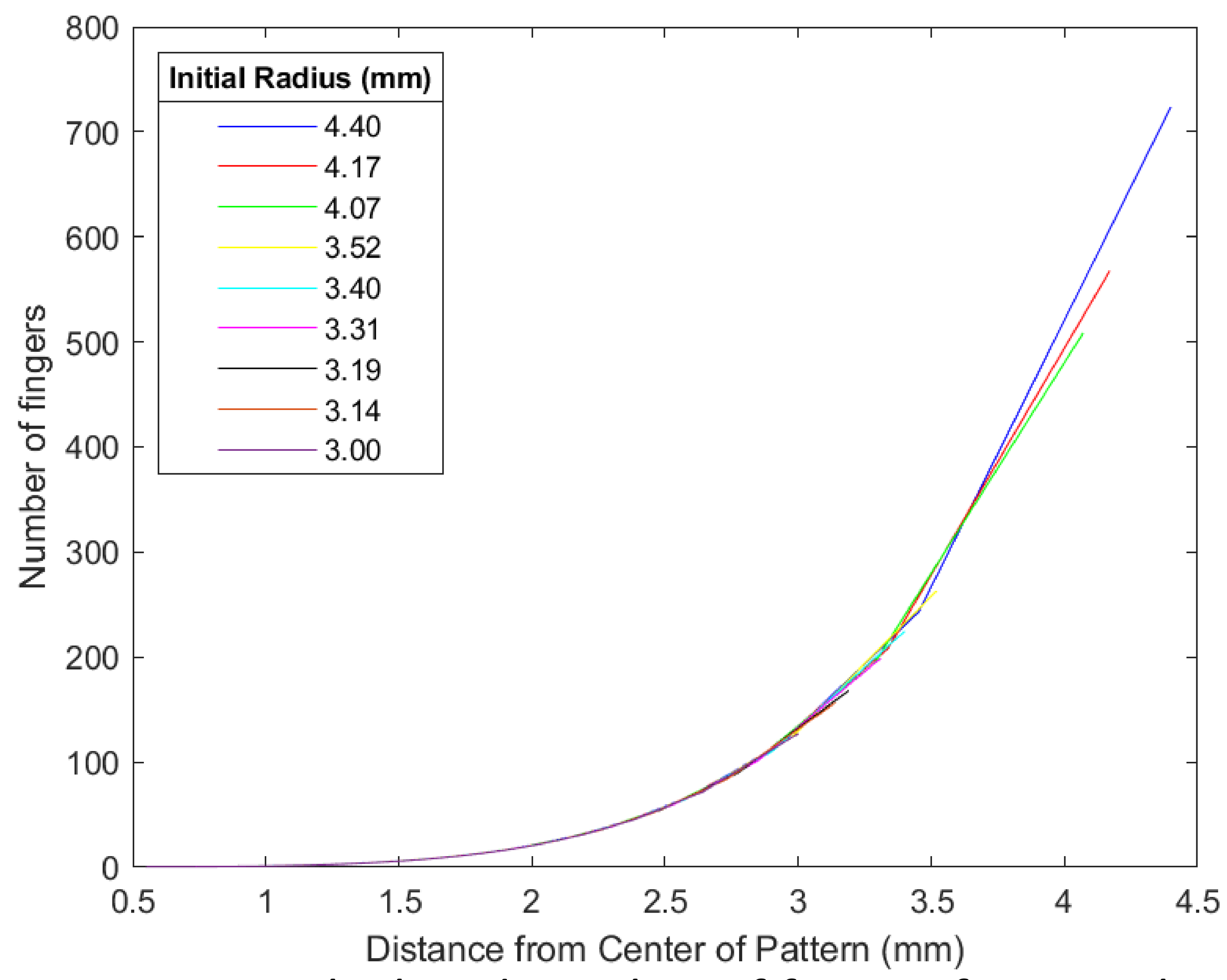

Figure 3: Calculated number of fingers for sample dendrites.

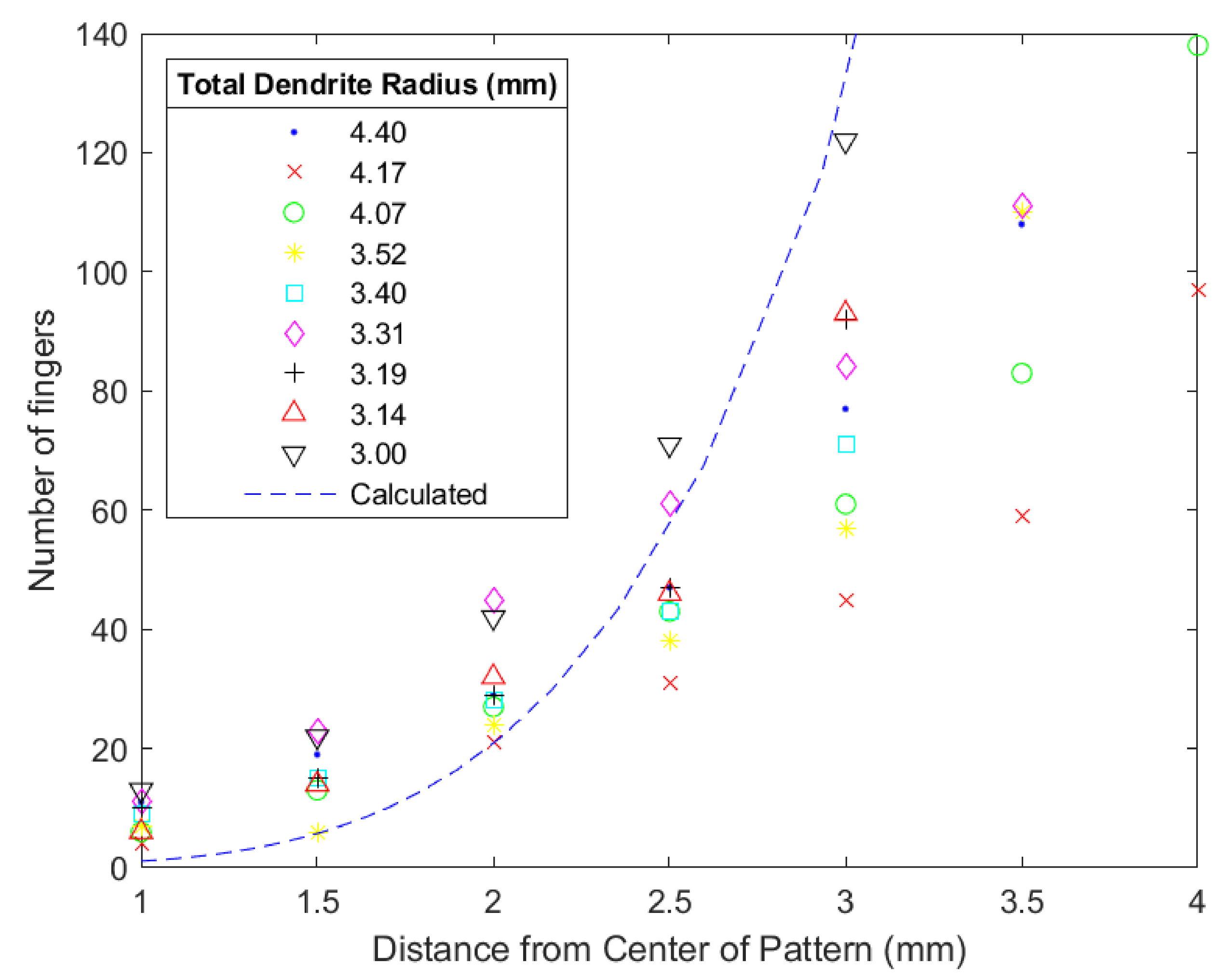

Figure 4: Counted number of fingers on sample dendrites.

- The calculated number of fingers was inaccurate at both small and large radii, but was relatively accurate in the range of 1.5 mm to 2.5 mm.
- The trend for the number of fingers in the model increases exponentially at a greater rate than the trend seen in reality.

References:

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