Modeling Clogging in Microfluidic Devices

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Background

- Clogs form when particles passing through a constricted channel create an arch that blocks flow
- Microfluidic devices are an ideal medium for observing clogs. Examples include:
  - water filtration systems
  - inkjet printers
  - blood vessels and biomedical devices
- Clear understanding of clogging can be used to prevent clogs, improving device performance and lifetime
- **Goal**: develop computational model to characterize how clogs form

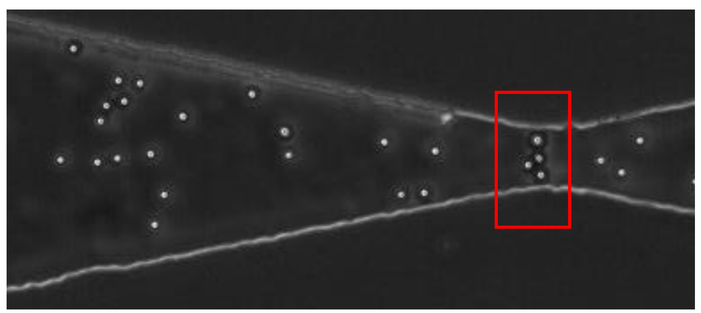
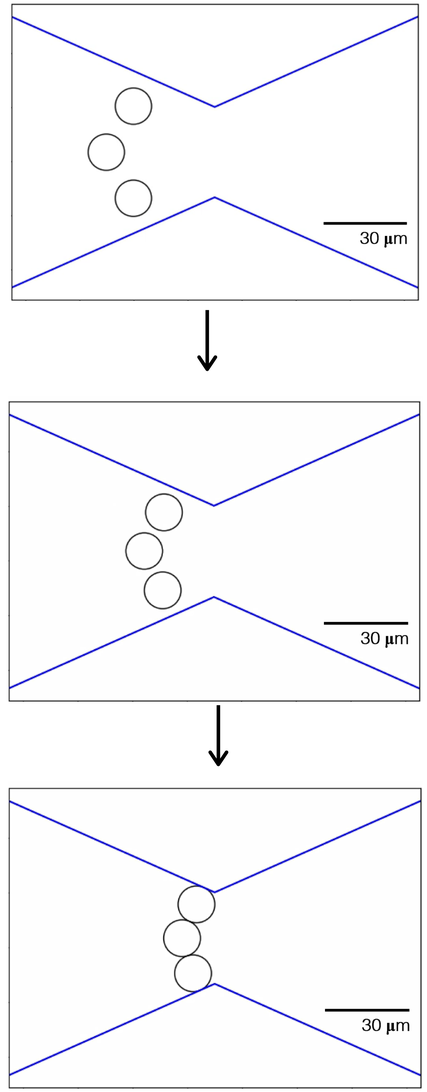


Figure 1: Photograph of a clog in a microfluidic device, marked in red. Particles form an arch over the channel constriction. Image from (Holway, 2018).

Methods

- Modeled the velocity profile of fluid flowing through a channel with a given geometry
- Calculated forces acting on particles in the fluid based on interactions with fluid, collisions, and friction
- Simulated particle motion through the channel
- Identified clogging events
- Analyzed stability of different clog configurations

Results



t = 0
Particles start out upstream of the constriction

Particles flow towards the constriction, transported by a carrier fluid

An arched clog forms and stabilizes. Friction prevents the particles from slipping through the constriction

Figure 2: the progression of a clogging event. Images show position of particles in a channel at different timesteps. Channel walls are marked in blue. Fluid flows left to right.

Conclusions

- It is possible to create a geometric clog that is held in place by its arch geometry rather than adhesive forces
- Clogs can form spontaneously
  - Not dependent on particle accumulation on walls
  - Clogs form when particles are in the right position at the same time to form an arch
- Friction improves clog stability
- Certain clog stuctures are metastable (only form temporarily)
  - Modeled 4 particle clogs that are metastable
  - Clogs without friction are metastable

Future Steps

- Explore effect of adhesive forces between particles and walls
- Use a more complex fluid dynamics model that accounts for particle positions disrupting flow
- Connect model to macroscopic properties of clogging

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