Megasupramolecules

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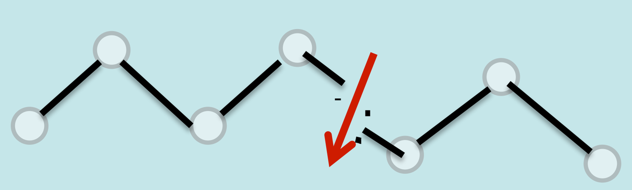
Background

Long-chain polymers have long been known to be useful in a variety of applications[1]

- Drag Reduction
  - Flow through a pipe experiences reduced friction (i.e. in Trans Alaska Pipeline)[2]
- Mist Control
  - Droplets formed are larger and fall faster, leading to less explosive mist
- Increased Elongational Viscosity
  - Desired feature in hydraulic fluids

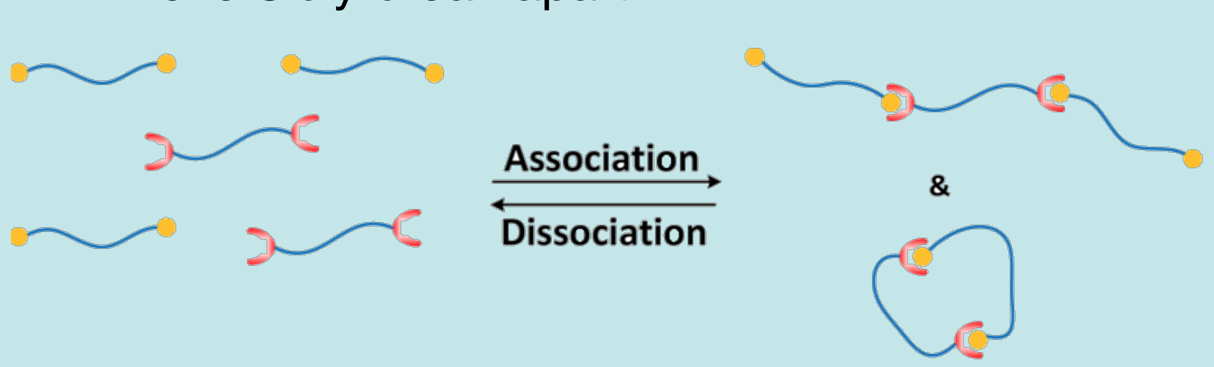
Chain Scission: Long-Chain polymers break in flow[3]

- Long-chain polymers under stress degrade due to chain scission (covalent bonds break)
- Pumping through pipelines, in fuel systems, etc. breaks chains, which decreases their effectiveness



Megasupramolecules: Benefits of long-chain polymers without permanent degradation[1]

- End-associative long telechelic polymers act like long-chain polymers in flow, but reversibly break apart

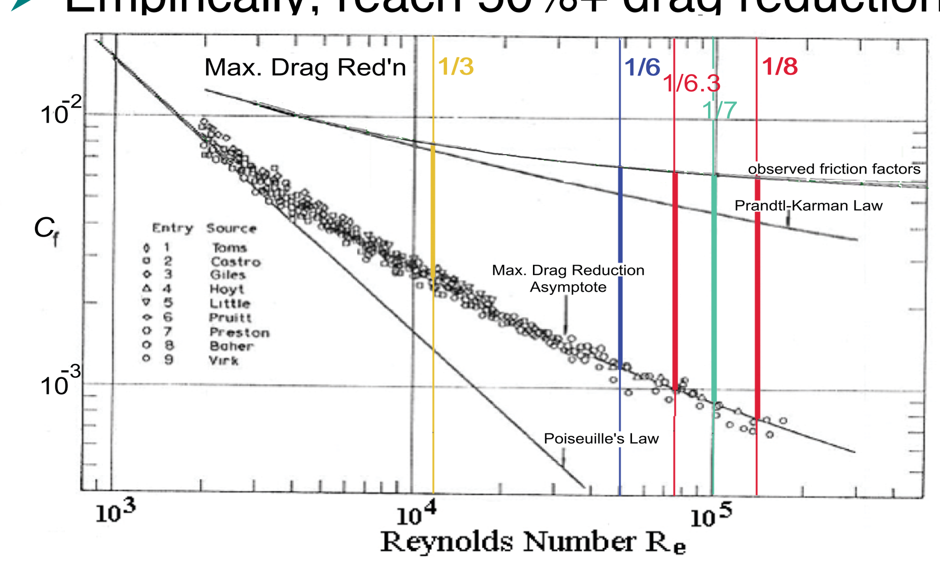


- Adjust length of backbone and strength of associative groups to tune behavior

Taming Turbulence

Drag Reduction has been known since the 1940s, but mechanism is not well understood[4]

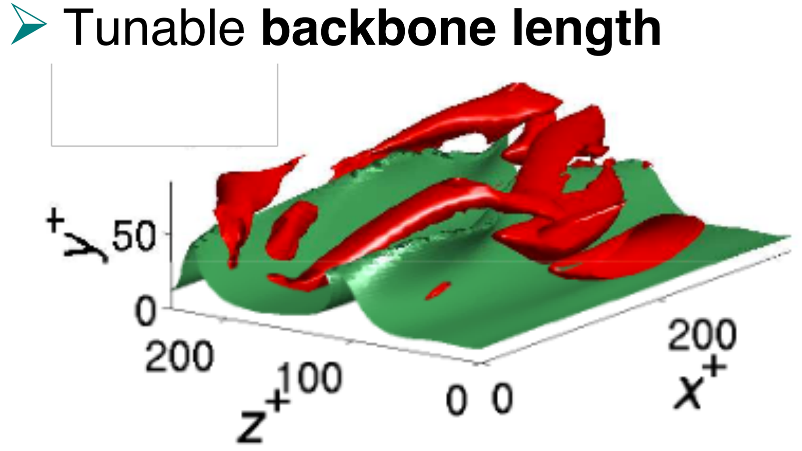
- Empirically, reach 50%+ drag reduction



Friction factor as a function of Re at maximum drag reduction (Adapted from Virk, *et al.* 1970)[5]

Using Megasupramolecules as molecularly designed probes of turbulence

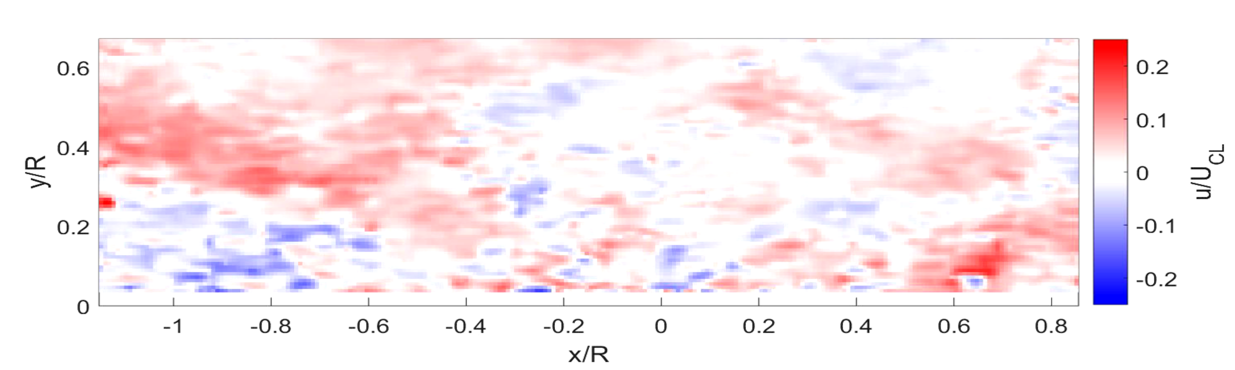
- Stable, reproducible
- Tunable **association strength**
- Tunable **backbone length**



Active turbulence (Wang, *et al.* 2014)[6]

Particle Image Velocimetry

- Collaboration with McKeon group (GALCIT)
- Observe the impact of megasupramolecules on turbulent flow



Snapshot of particle image velocimetry data for water

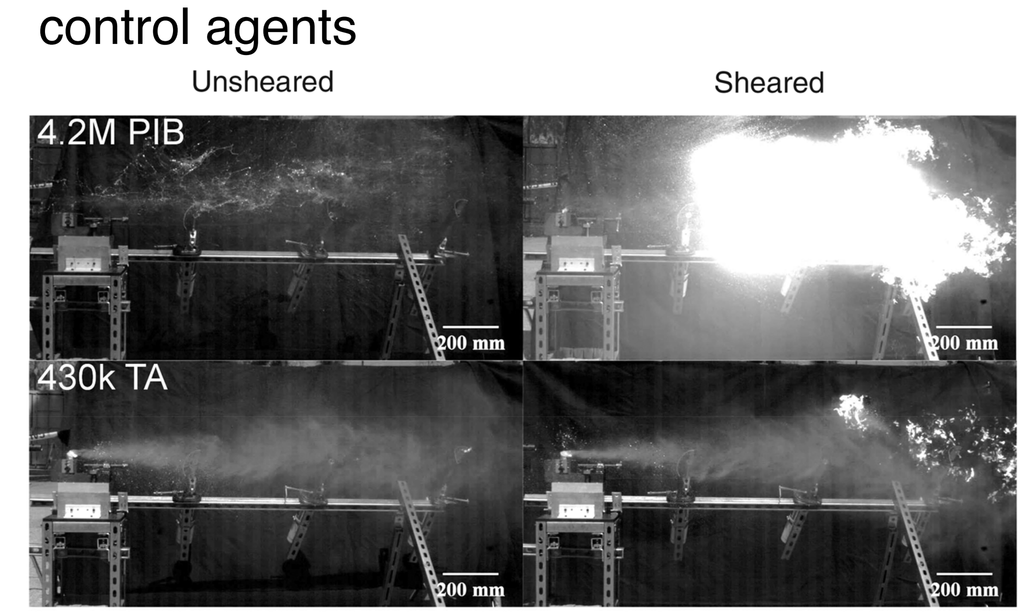
Controlling Droplets

In an impact event, droplets of fuel or other flammable liquids can be sprayed in a mist

- Fine mists are highly flammable compared to larger droplet mists[1]
  - Small droplets evaporate quickly and feed fires
  - Larger drops fall and can even extinguish other fires

In fuel, megasupramolecules work as robust mist control agents, but still allow engine combustion

- Drop break-up is changed by long-chains
- Quantifying drop sizes and break-up behavior allow for design of better mist control agents



Unsheared vs. sheared mist control results for a long-chain polymer (polyisobutylene) compared to megasupramolecules (Wei, *et al.* 2015)[1]

Designing megasupramolecules to target mist control at low concentration

- "Goldilocks" problem:
  - Too little polymer—not enough mist control
  - Too much polymer—inhibits end-use in real-world applications

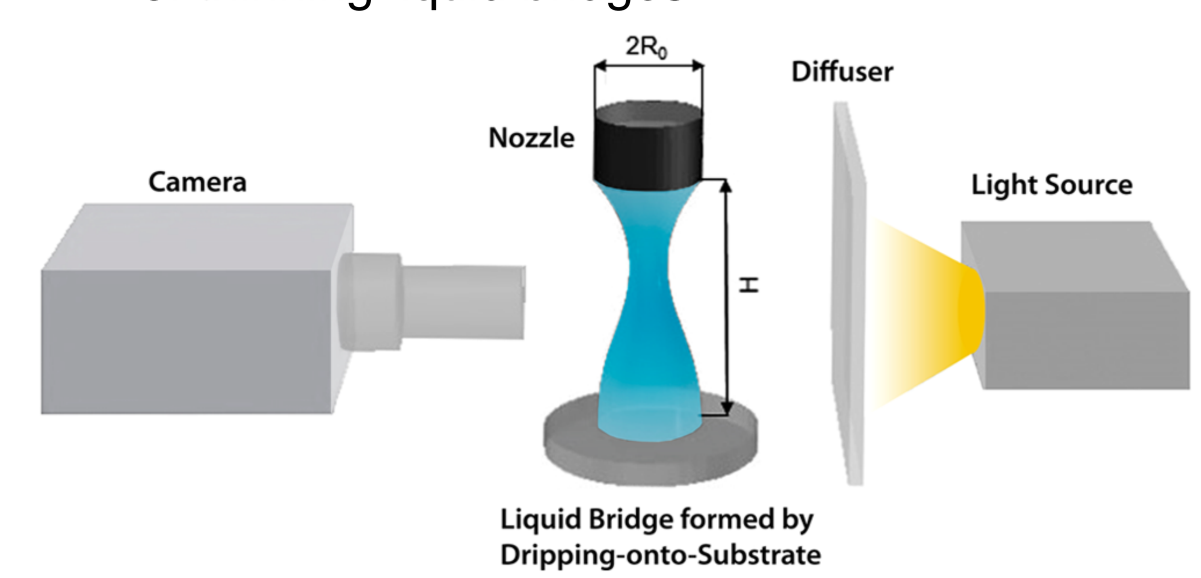
Modifying Extensional Viscosity

Extensional Viscosity controls Drag Reduction and Mist Control

- Polymers stretching is tied into how droplets form and how polymers interact with turbulence

Measuring Extensional Viscosity of low concentration solutions is challenging

- Requires very fast measurements at very small length scales
- Building a dripping-on-substrate rheometer based on work of Sharma, *et al.* using a high-speed camera to measure the width of thinning liquid bridges



Cartoon of a dripping-on-substrate rheometer for measuring extensional viscosities of low viscosity solutions (Dinic, *et al.* 2015)[7]

References

1. Wei, M.-H. *et al.* (2015).
2. Burger, E. D., Munk, W. R. & Wahl, H. A. (1982).
3. Brostow, W. (1983).
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5. Virk, P. S., Mickley, H. S. & Smith, K. A. (1970).
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