Novel fractionation methods: Separation of MFC in a viscoplastic fluid

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RETHINK PAPER:
Lean and Green

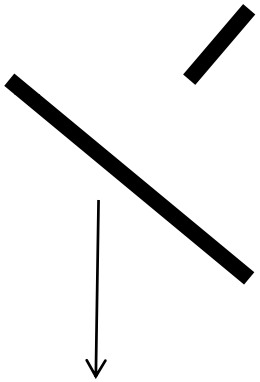
Introductory Comments

- Objective – methodology to purify commercially available MFC
- Assess enhancement in paper properties
- Motivation/efficiency

Part 1. Understanding efficiency: the toy problem

Toy Problem

Goal: Separation of rods based upon length through settling



Ideal conditions: Stokes flow (Re=0), isolated (C=0), quiescent flow fiel

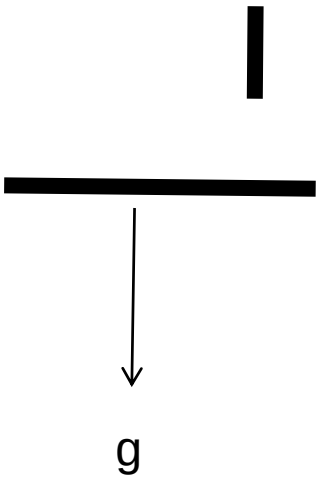
$$\mathbf{u} = \frac{\Delta\rho d^2}{16\mu}\left[\left(\ln 2r + 0.193\right)\mathbf{g} + \left(\ln 2r - 1.807\right)\left(\mathbf{p}\cdot\mathbf{g}\right)\mathbf{p}\right]$$

p = orientation
r = aspect ratio
g = gravity

- no unique settling velocity! Settling velocity dependent on orientation
- drift velocity of the same order of magnitude as settling

Toy Problem

Goal: Separation of rods based upon length through settling



Ideal conditions: Stokes flow (Re>0), isolated (C=0), quiescent flow fiel

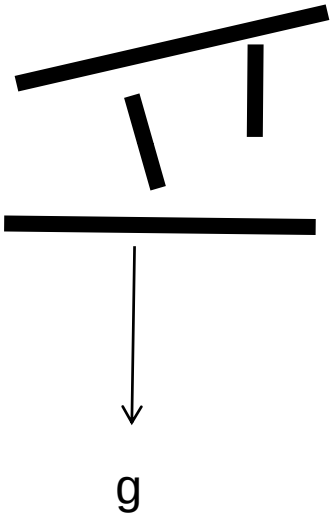
$$\rho C_d(u)u^2 = \frac{g\Delta\rho V}{A}$$

Mass/area

- stress acting on the particle is not symmetric
- adopts preferential orientation (horizontal)

Toy Problem

Goal: Separation of rods based upon length through settling



Ideal conditions: Stokes flow (Re>0), isolated (C>0), quiescent flow fiel

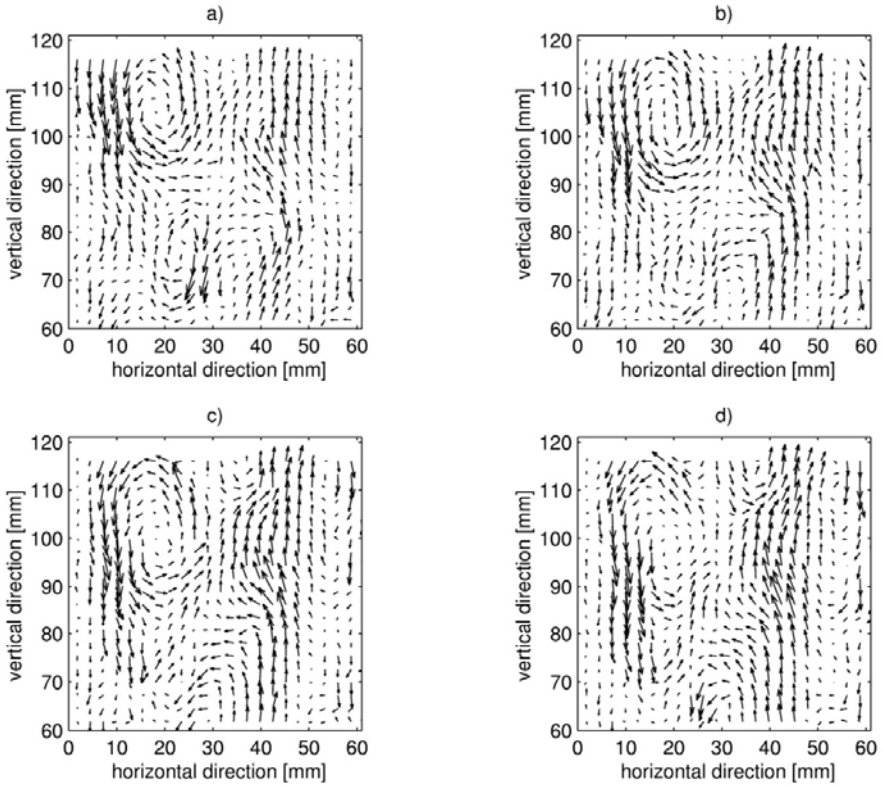
- stress acting on the particle is not symmetric
- long range hydrodynamic disturbances (chaotic)

Flow Visualization: PIV Results

N = 0.01

N = 5

Salmela et al AIChE J. (2007)

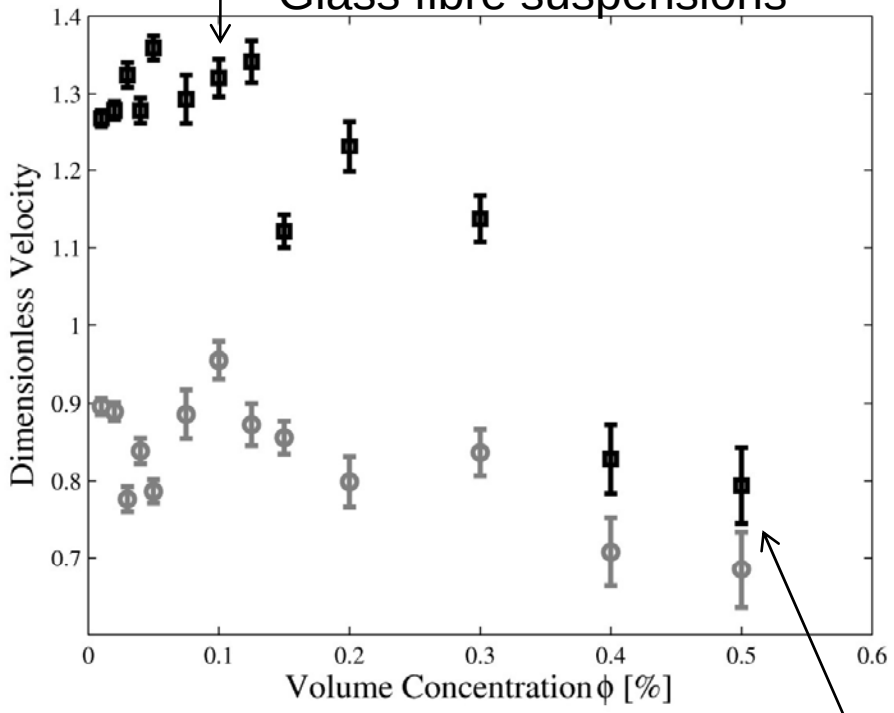


Holm et al Progress in paper Physics (2005)

Is Separation Possible under ideal conditions?

Separation under dilute conditions

Glass fibre suspensions



Salmela et al, FRC, Oxford, 2009

Papermaking fibre suspensions

PET results indicate no significant differences in settling velocity of different fractions in mechanical pulp suspension

Martinez et al FRC Oxford 2001

No separation at Higher concentrations (N~5)

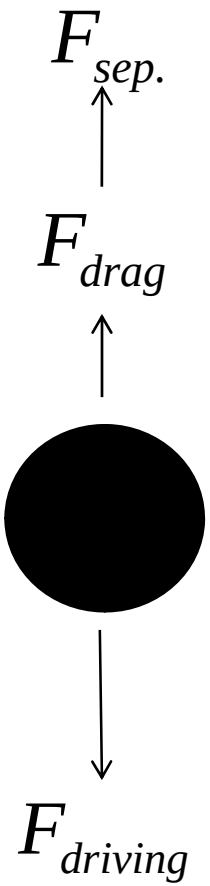
- **Part 2. The Novel Principle**

Goal:

- dampen long range interaction (isolated particle)
- separation based upon physical property

Toy Problem

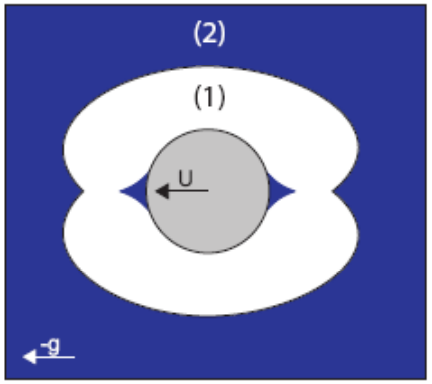
A new threshold for motion



Separating force has two functions:

- dampen ALL disturbances
- create the separation principle

Solution: Change the rheology !



Beris et al., JFM 1985

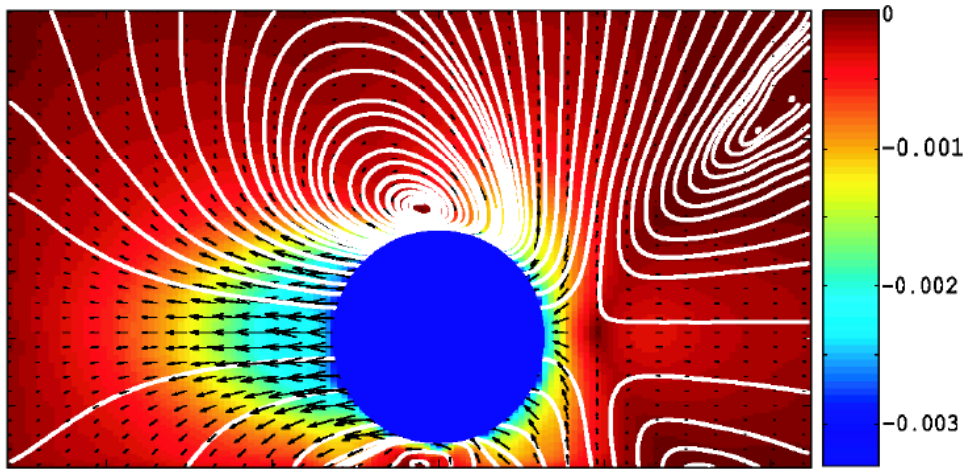
Dampen the forces

Separation Principle

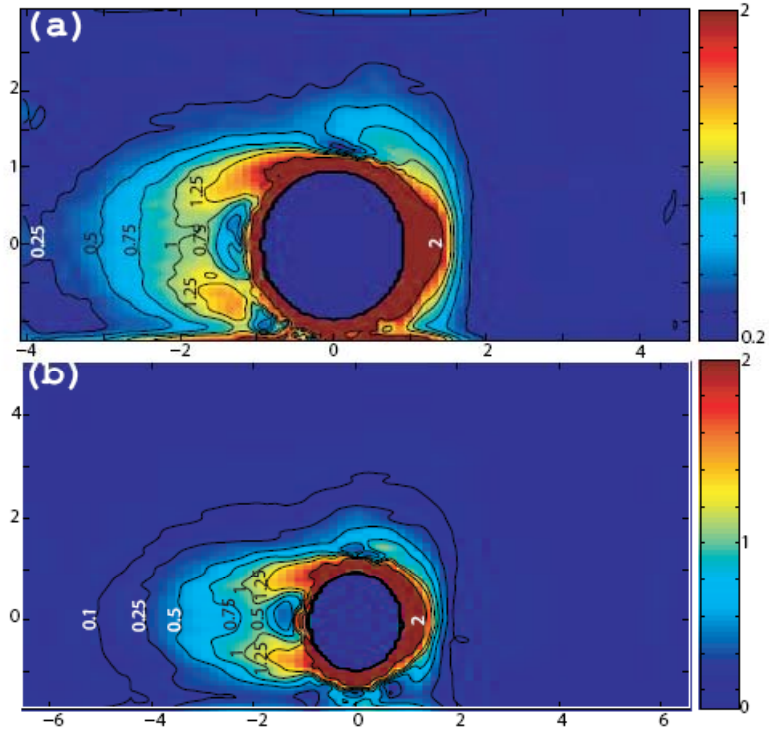
$$\frac{F_{driving}}{F_{sep}} = \frac{g\Delta\rho V}{\tau_y A} > 1$$

Mass/area

Estimates of the Interaction Area



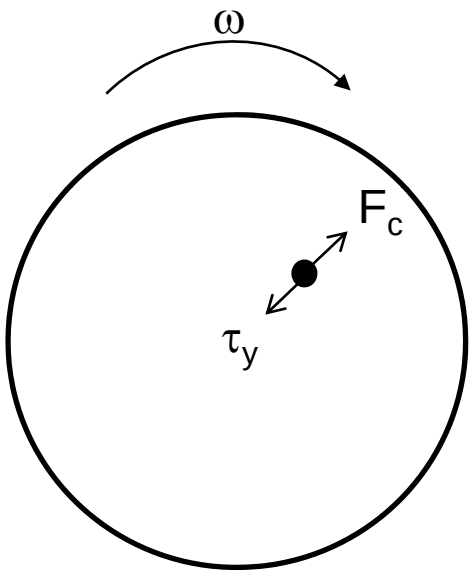
Flow Field



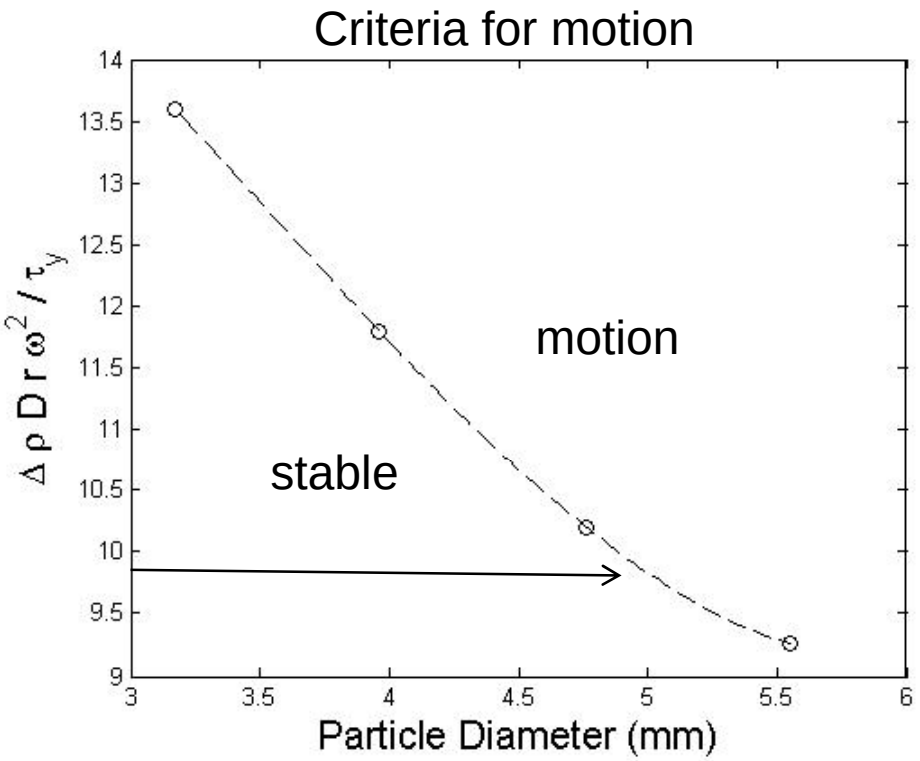
Second Invariant of the strain rate tensor

Putz, Burgehela, Martinez & Frigaard, Phys Fluids 2008

Initial Experiments



centrifuge



Proof of Principle

Centrifuge Test with a Yield Stress Fluid

Suspension of black and red particles

start

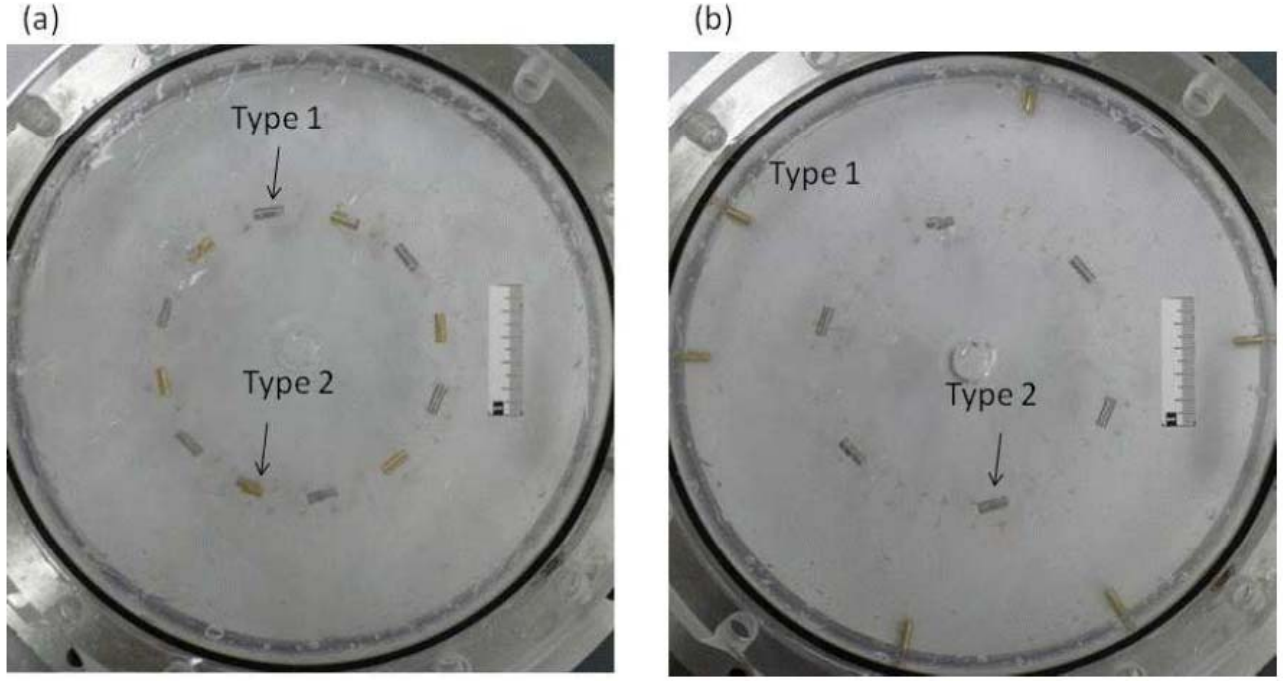
Migration of black particles

Finish

Proof of Principle

Centrifuge Test with a Yield Stress Fluid

Different density rods



Start

Finish

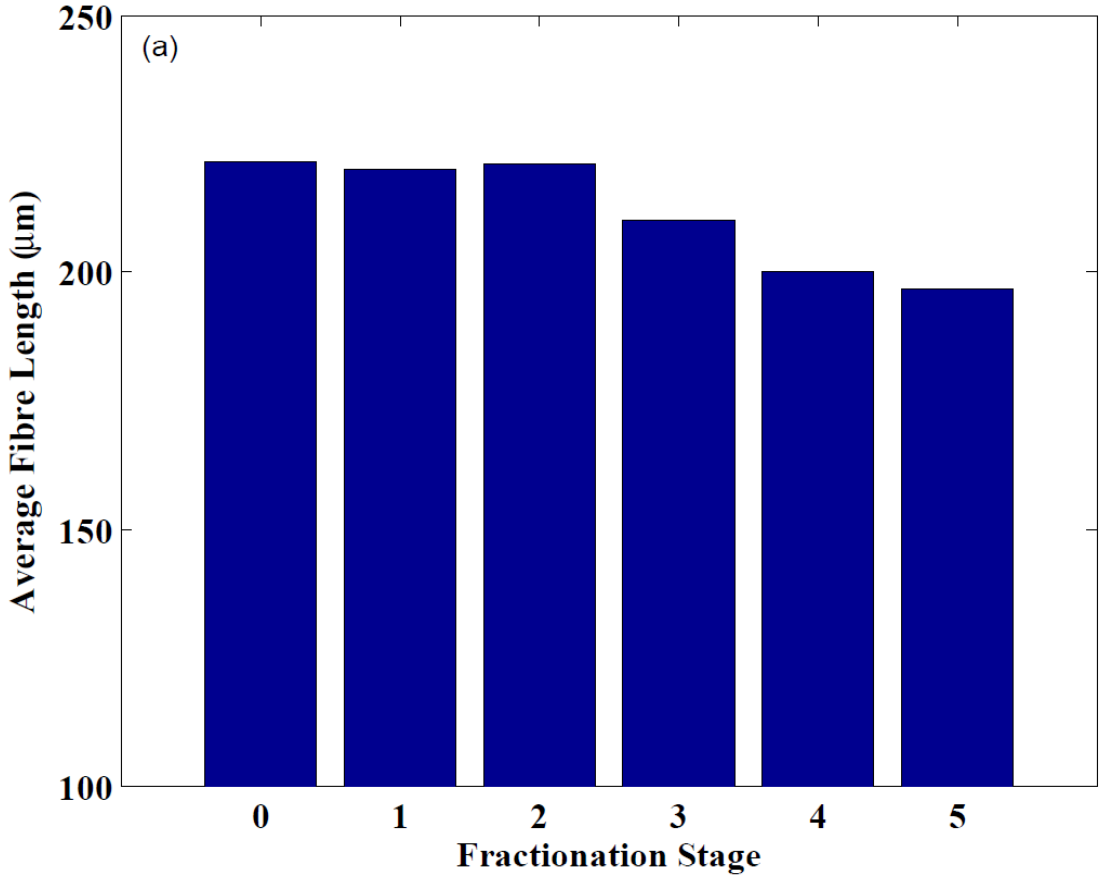
- **Part 3.** Demonstration Separations

Goal:

- Purification of commercially available MFC
- Reliable manufacturing method

Comparison of Methods

Pressure Screen

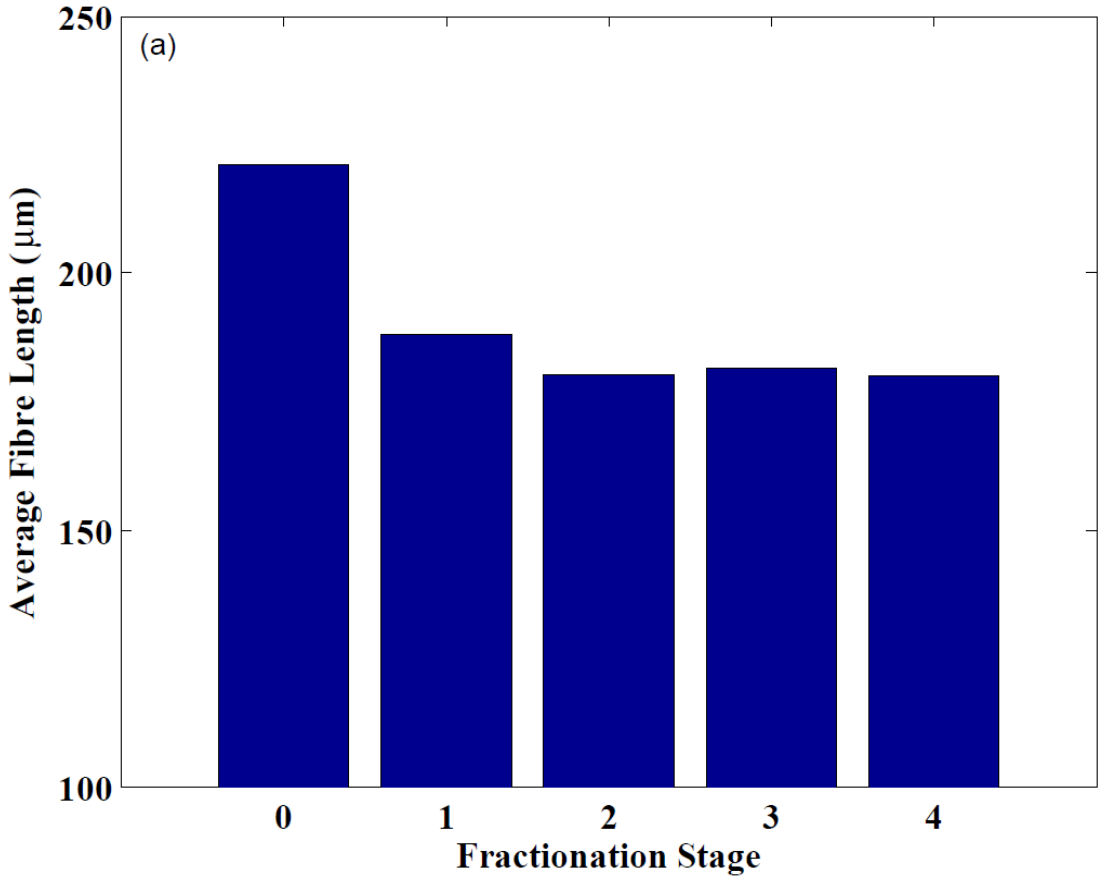


Conditions

- 0.1% MFC shown
- Tested at : 0.1,0.3,0.5,0.6 and 1%
- Metso FS-03
- rotor speed 3500 rpm
- Reject ratio 60%
- Screen sizes:
  - Stage 1 : 0.13 mm
  - Stage 2 : 0.09 mm
  - Stage 3-5: 0.06 mm

Comparison of Methods

Hydrocyclone

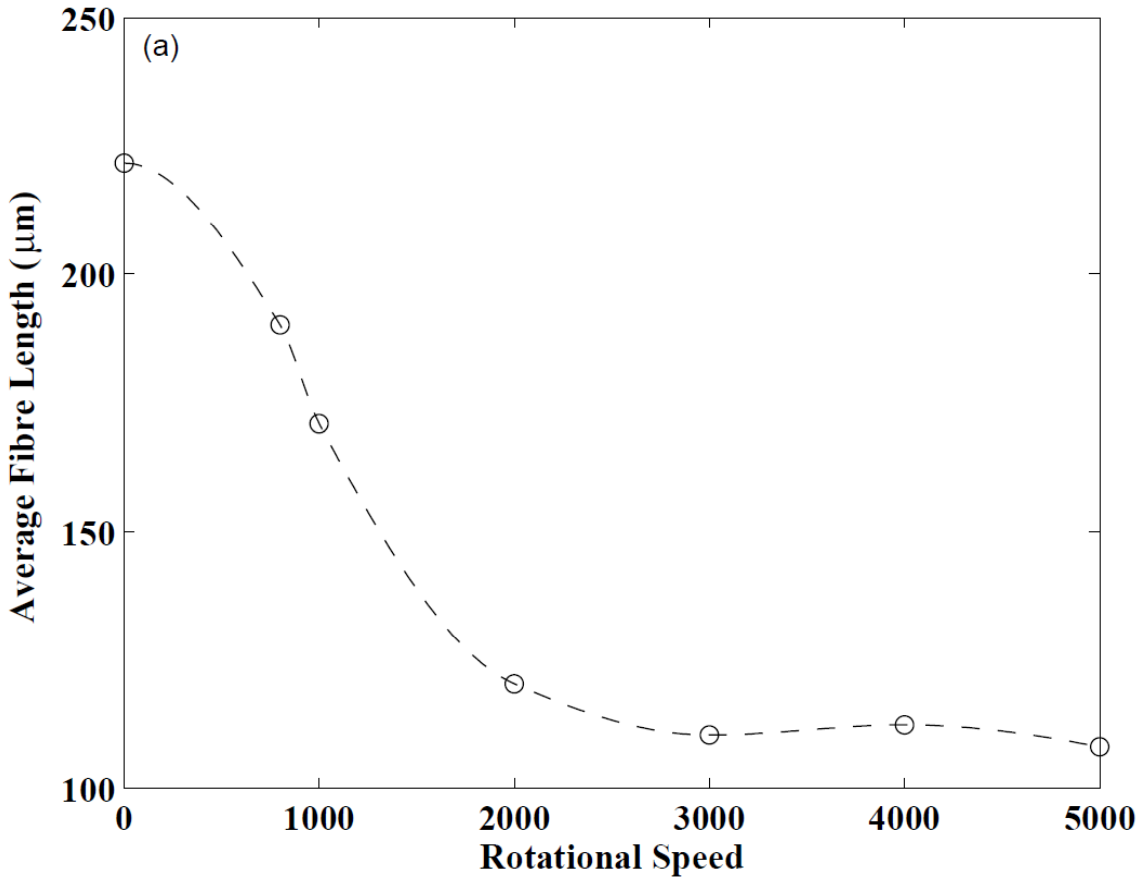


Conditions

- 0.2% MFC shown
- C-1201 Microspin polypropolyene hydorcyclone
- 10 mm diameter
- 5 bar, 4.2 lpm
- ``accept" refractionated

Comparison of Methods

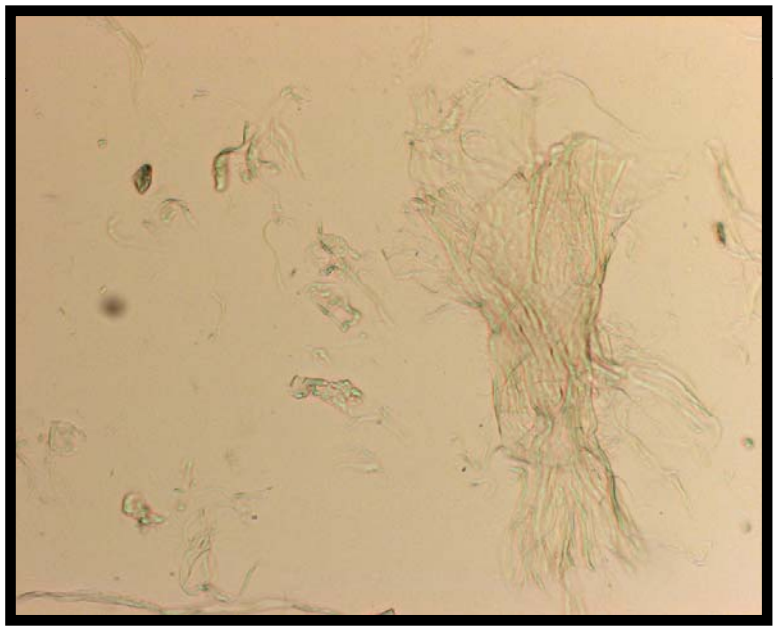
Gel Technique



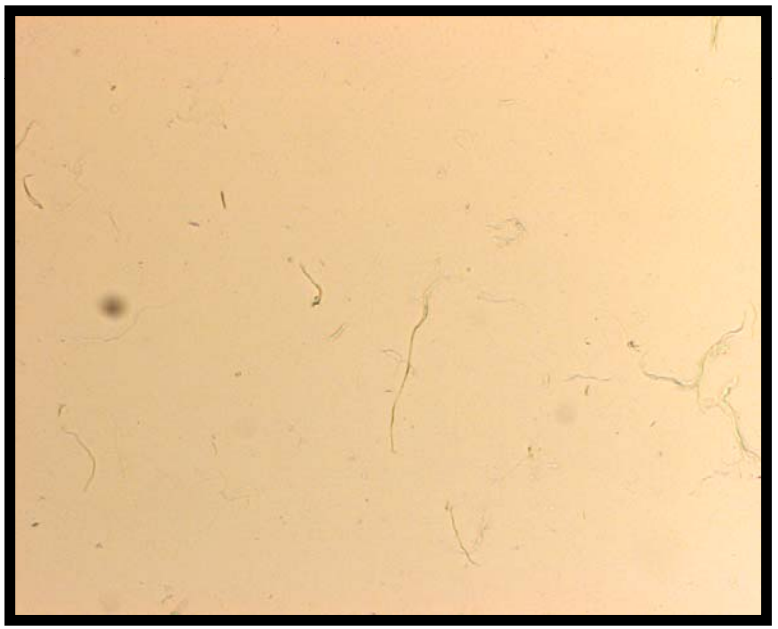
Conditions

- 0.2% MFC shown
- 0.16% Carbopol 940 (pH 7)
- MFC
  - 0.1, 0.2 0.4 and 0.6%
- Eppendorf 5804 centrifuge

Optical Microscopy

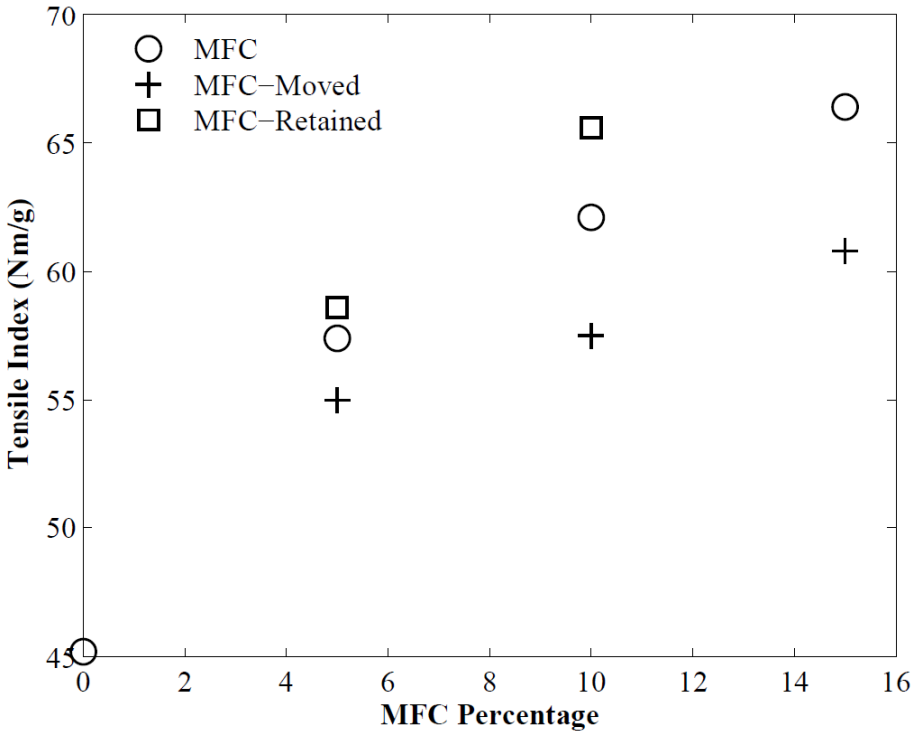


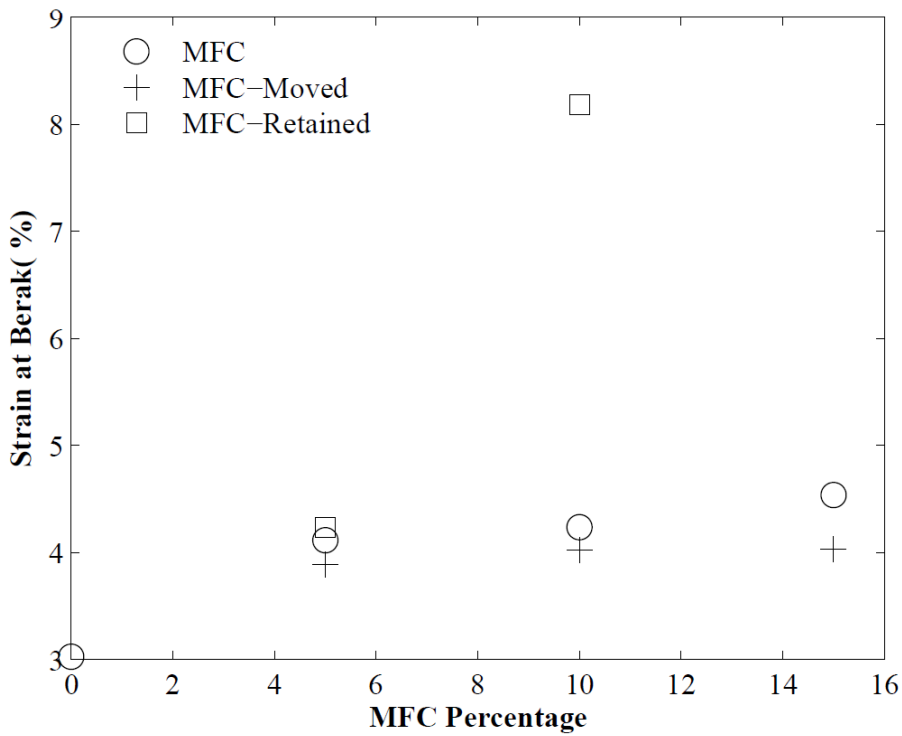
Before



After

Paper Properties





Standard handsheet, 60 g/m^2, bleached hardwood

Summary

- MFC – purification much different than traditional papermaking suspension
- Novel fluid: yield stress to determine separation based upon specific surface (mass/area)
- Number of demonstration separations outline utility
- Enhanced tensile and strain to break over commercially available material