Aalto University
School of Chemical Technology

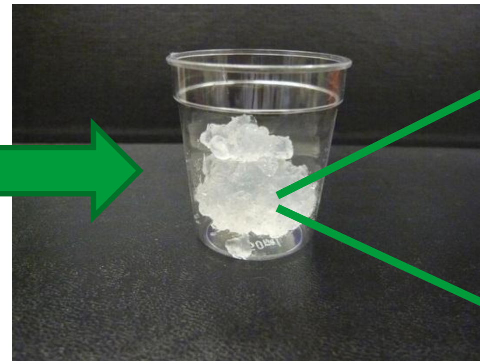
Rheology of MFC water suspensions

Anni Sorvari[1], Tapio Saarinen[1], Jukka Seppälä[1]
Juha Salmela[2], Sanna Haavisto[2]

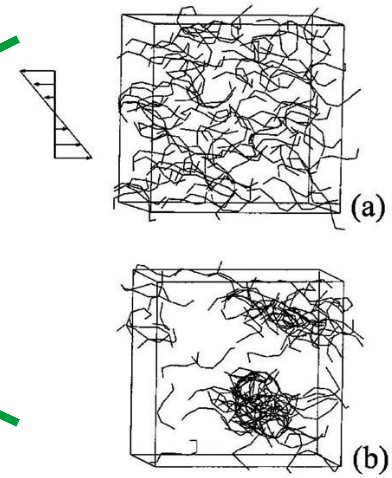
[1]Polymer Technology, Aalto University, Finland
[2]VTT, Multi Phase Flows Team, Finland

New nanosized fiber material from wood

http://fi.wikipedia.org/wiki/Koivut



Innventia, http://en.wikipedia.org/wiki/Nanocellulose



Microfibrillated cellulose is made from pulp or other cellulosic raw material

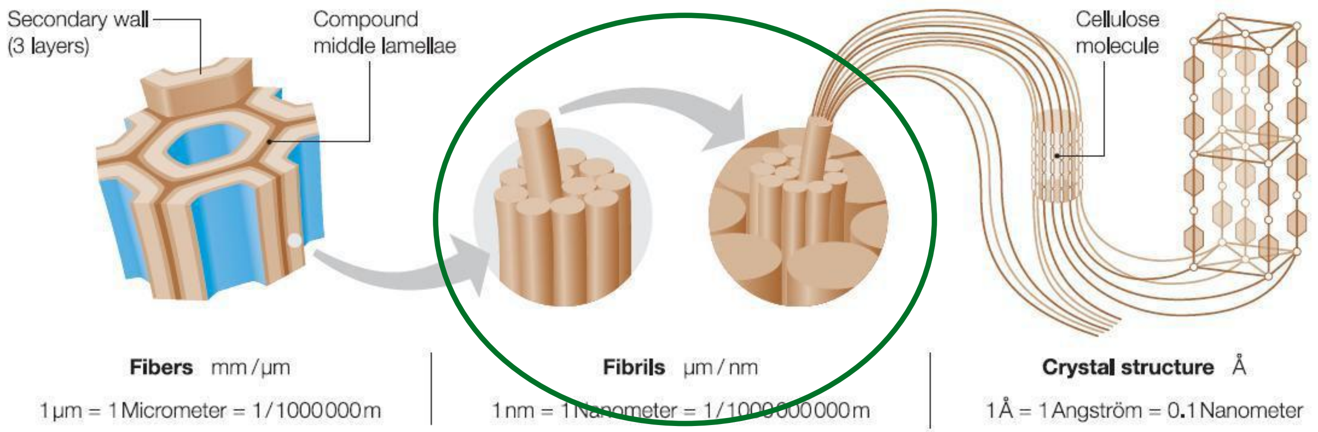
As a nanofiber material it has interesting rheology with a tendency to form flocs

Reliable measuring of flow properties with a rotational rheometer and imaging methods

2D photographs

3D OCT ”images”

Microfibrillated cellulose (MFC) is made from pulp by high mechanical shearing



Zimmermann et al. Adv. Eng. Mater. 6 754-761 (2004)

- Diameter 5-30 nm, length of several microns
- Inherently entangled network

Applications:

-nanocomposites

-paper and board

-oil drilling fluids

-rheology modifier for food and cosmetic industry

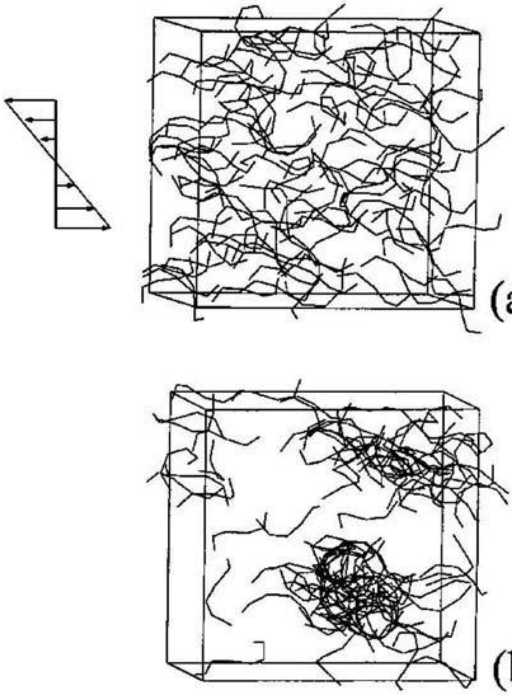
Yano et al. Advanced Materials (2005) 17 (2) 153-155.

Aalto University
School of Chemical Technology

Flocculated nature of MFC causes challenges to the rheometer

- Flocculation mechanisms
  - Mechanical flocculation
  - Negative surface charge

    → repulsion
- MFC forms flocs in water suspension (~similar to pulp)
  - How can we measure this kind of heterogeneous material?
  - How does the structure affect the rheological properties of MFC?

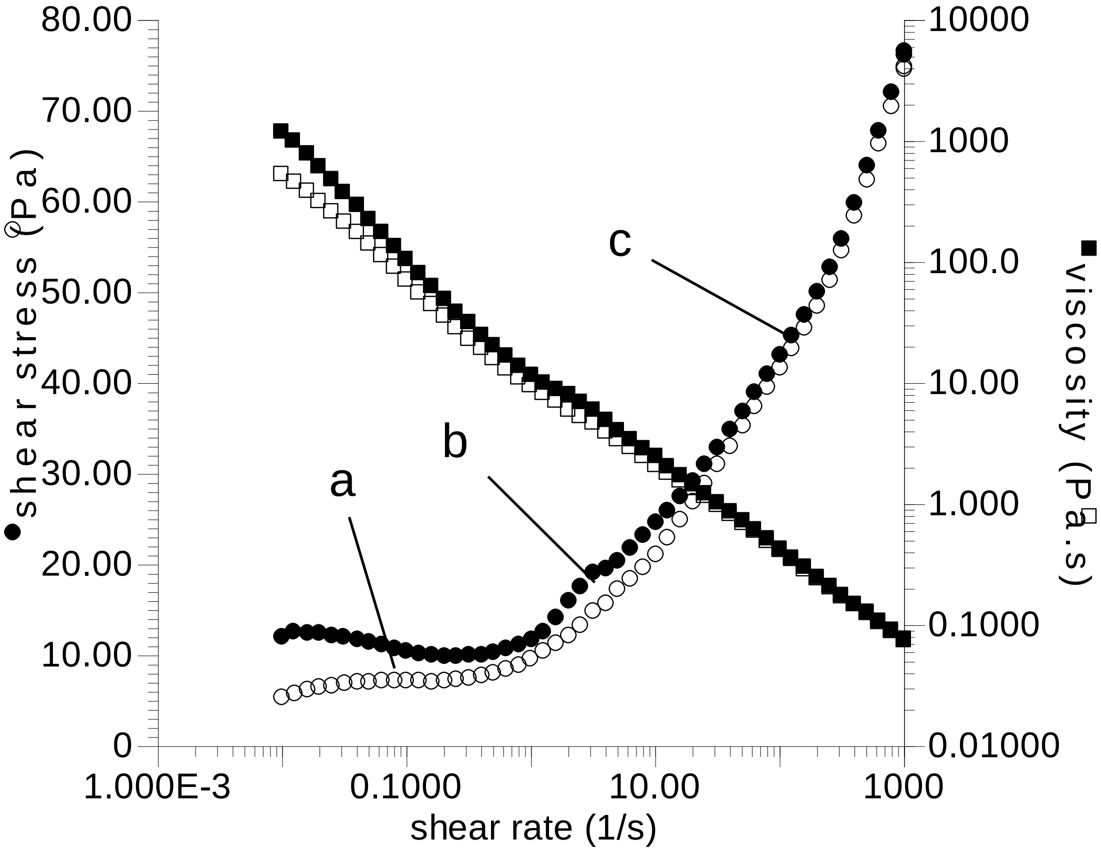


Richard J. Kerekes, Rheology of fibre suspensions in papermaking: An overview of recent research, Nord Pulp Pap Res J, 2006, 598-612.

By using a transparent sample cup, we can see the floc structure

- Rotational rheometer with “normal” and transparent outer cup
- Photographing the suspension with Nikon D90 camera with macro objective
- ”3D images” with optical coherence tomography (OCT)

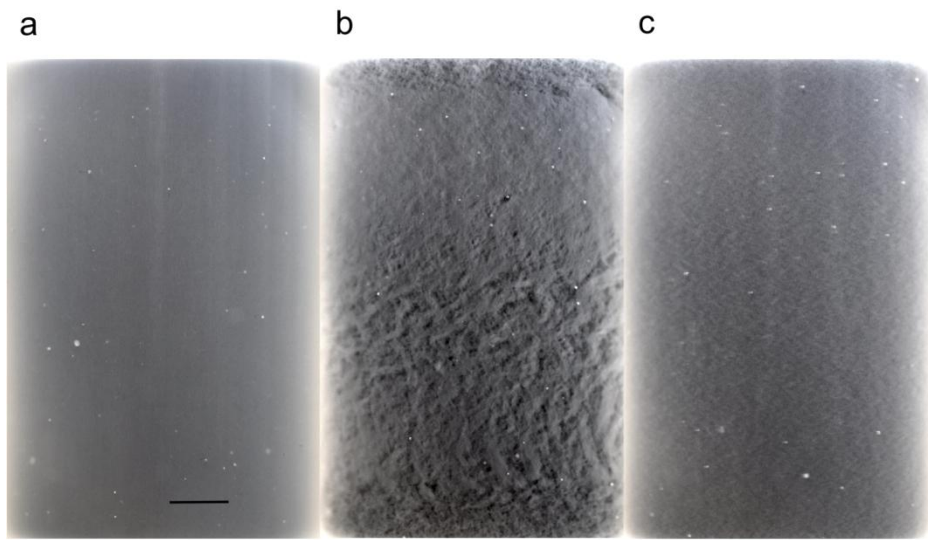
Aalto University
School of Chemical
Technology



3 regions in the flow curve

Filled symbols – metal cup

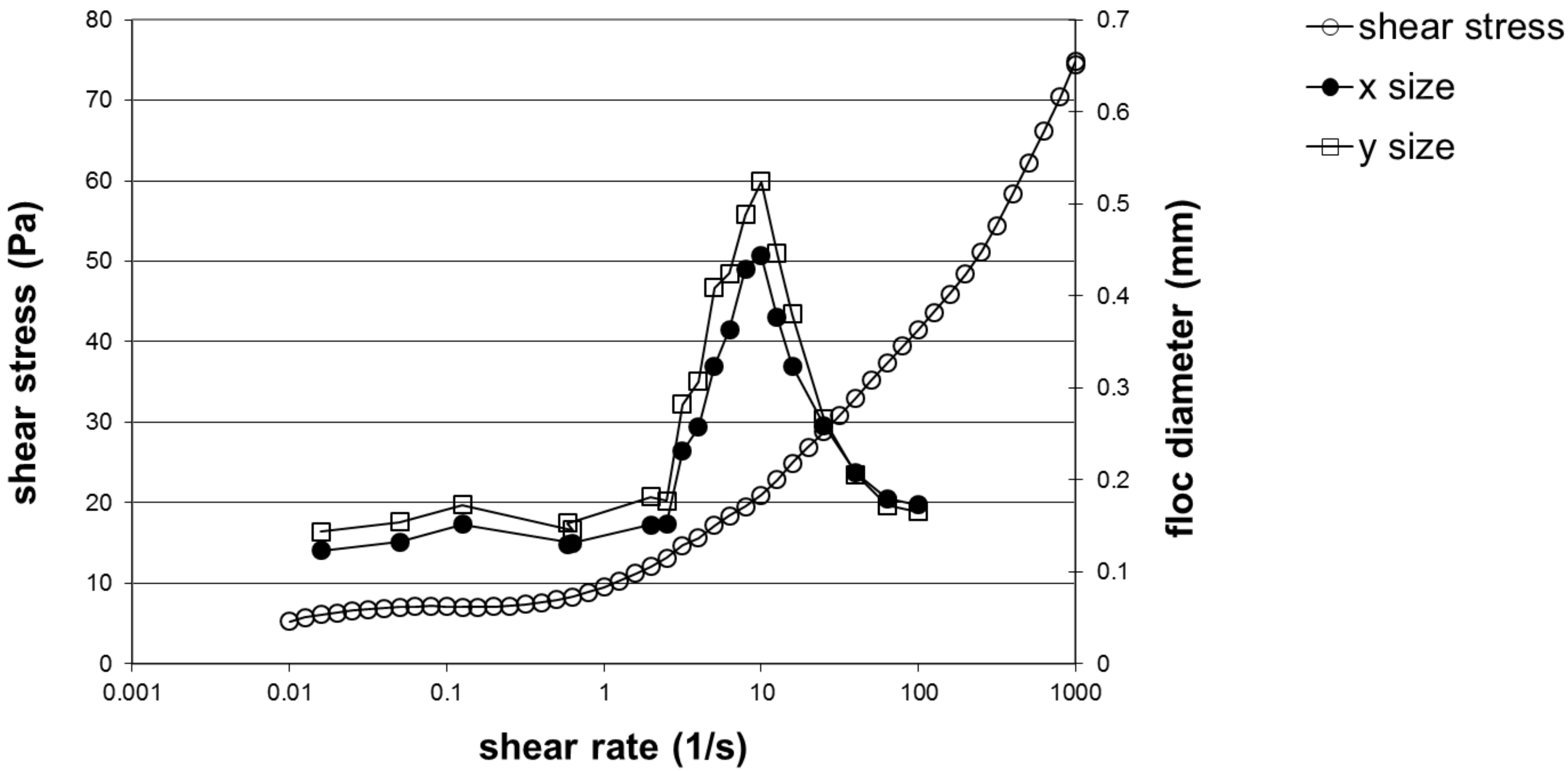
Unfilled symbols – transparent cup



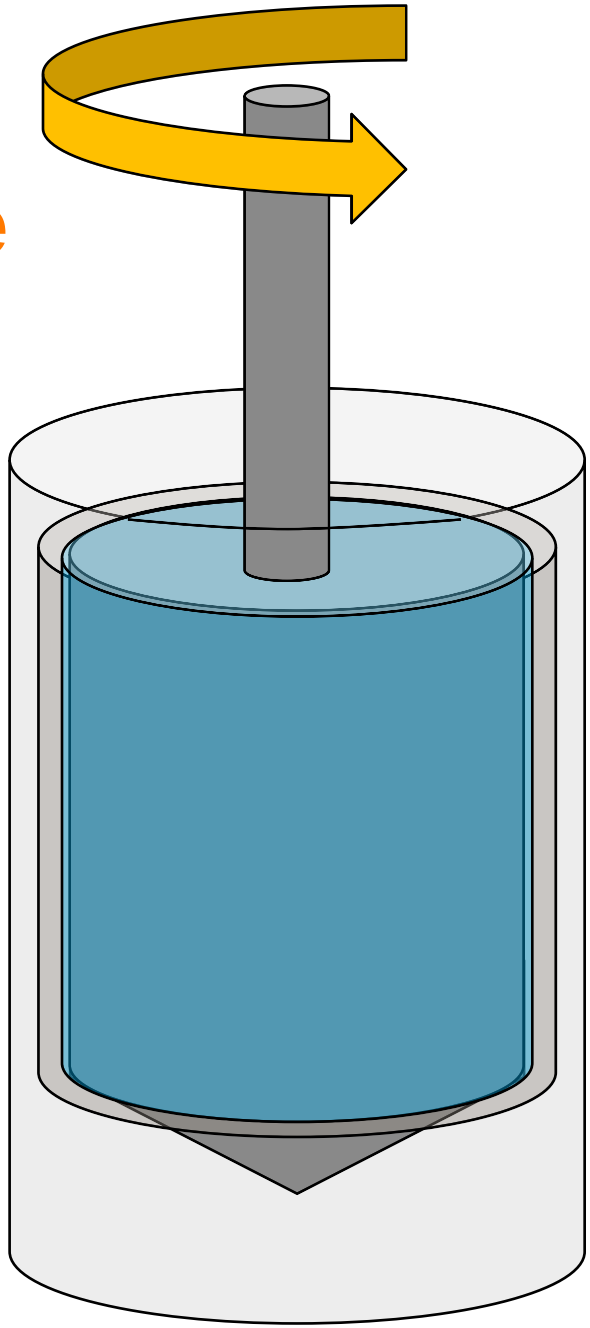
3 different floc structures

Saarikoski E, Saarinen T, Salmela J, Seppälä J (2012) Cellulose DOI 10.1007/s10570-012-9661-0.
Karppinen A, Saarinen T, Salmela J, Laukkanen A, Nuopponen M, Seppälä J (2012) Cellulose DOI 10.1007/s10570-012-9766-5.

Floc size vs. shear rate



Possible contributors in addition to floc structure



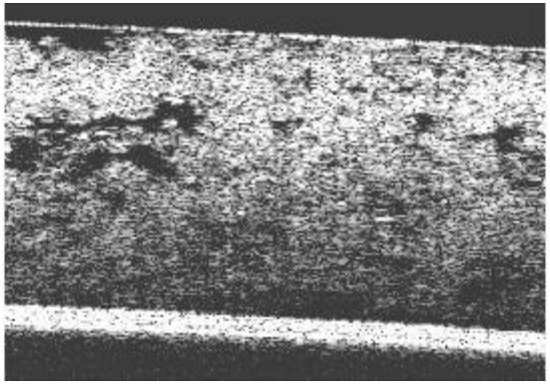
Wall depletion

Shear banding

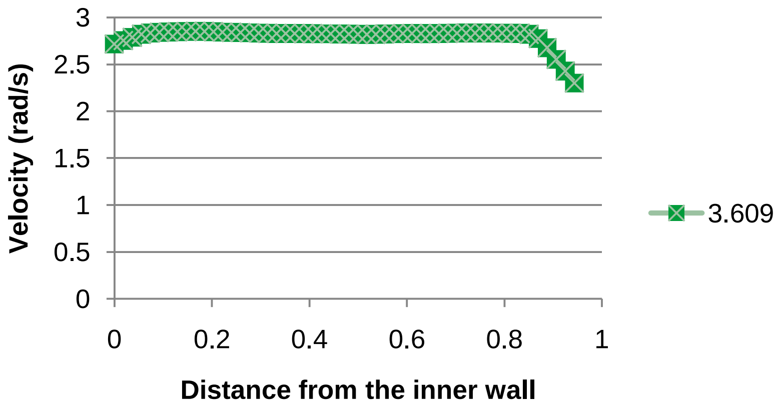
These both violate the assumptions that are made when calculating viscosity, moduli etc. from the raw data

We need 3D information of the structure

More information with OCT (optical coherence tomography)



Slice images of 3D objects (through the gap), micrometer resolution



Velocity profile through the gap

Collaboration with Sanna Haavisto & Juha Salmela, VTT

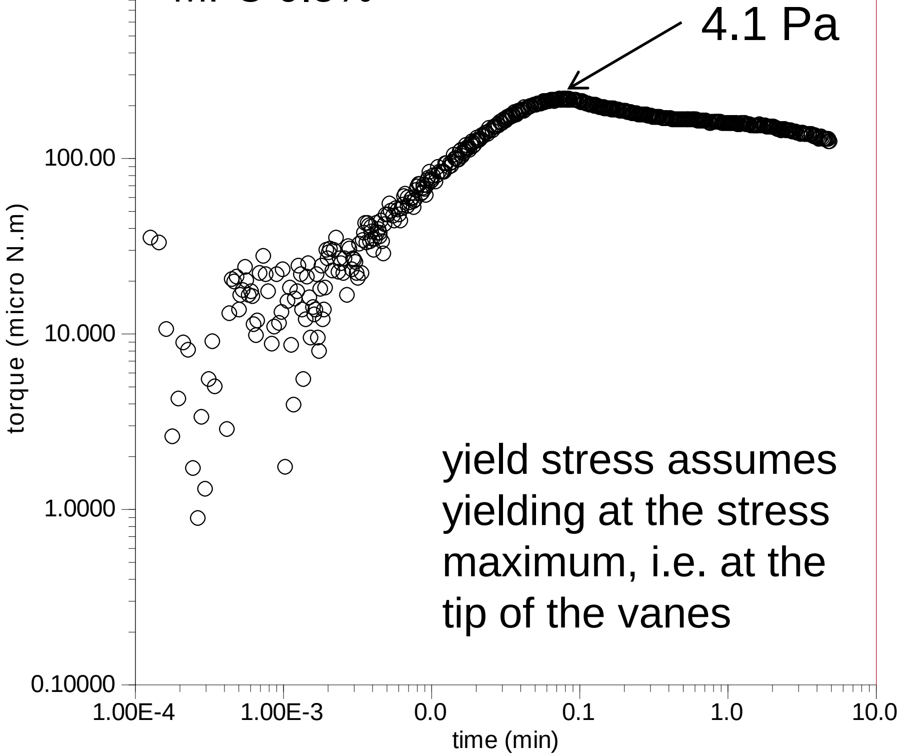
Yield stress determination without wall depletion

- Yield stress determined in a ”large” beaker and with vaned rotor by two methods:
  - Start-up of steady shear
  - Logarithmic continuous stress ramp

Two ways to measure yield stress in a ”large” beaker – similar results

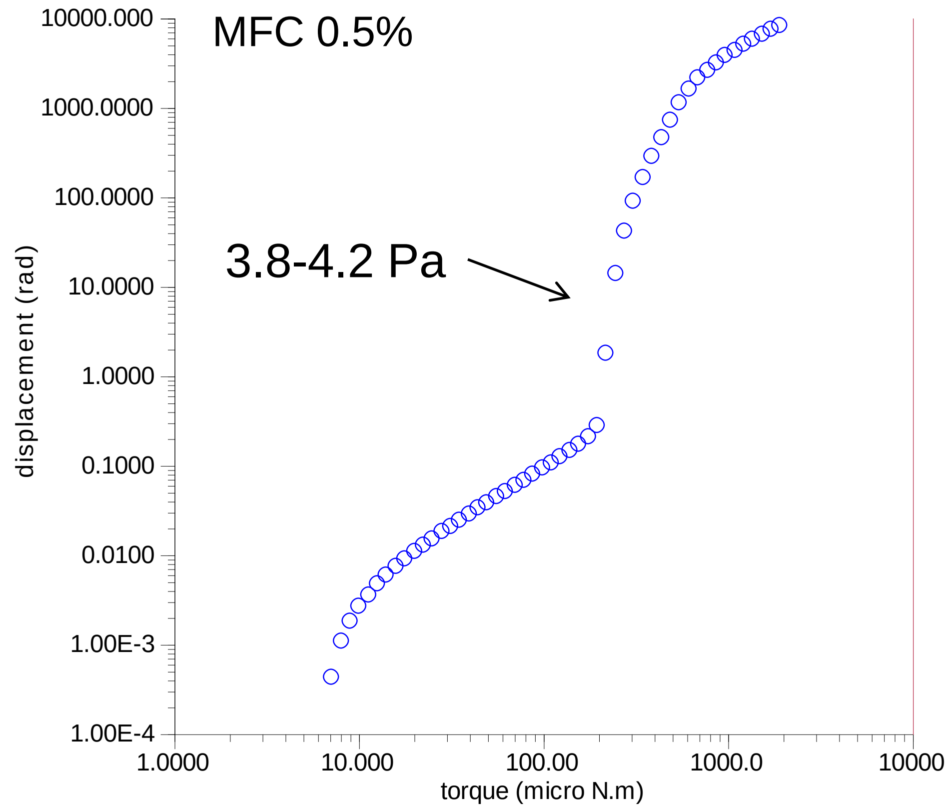
Vaned rotor in a large beaker

Start-up
Shear rate 0.068 rad/s
MFC 0.5%



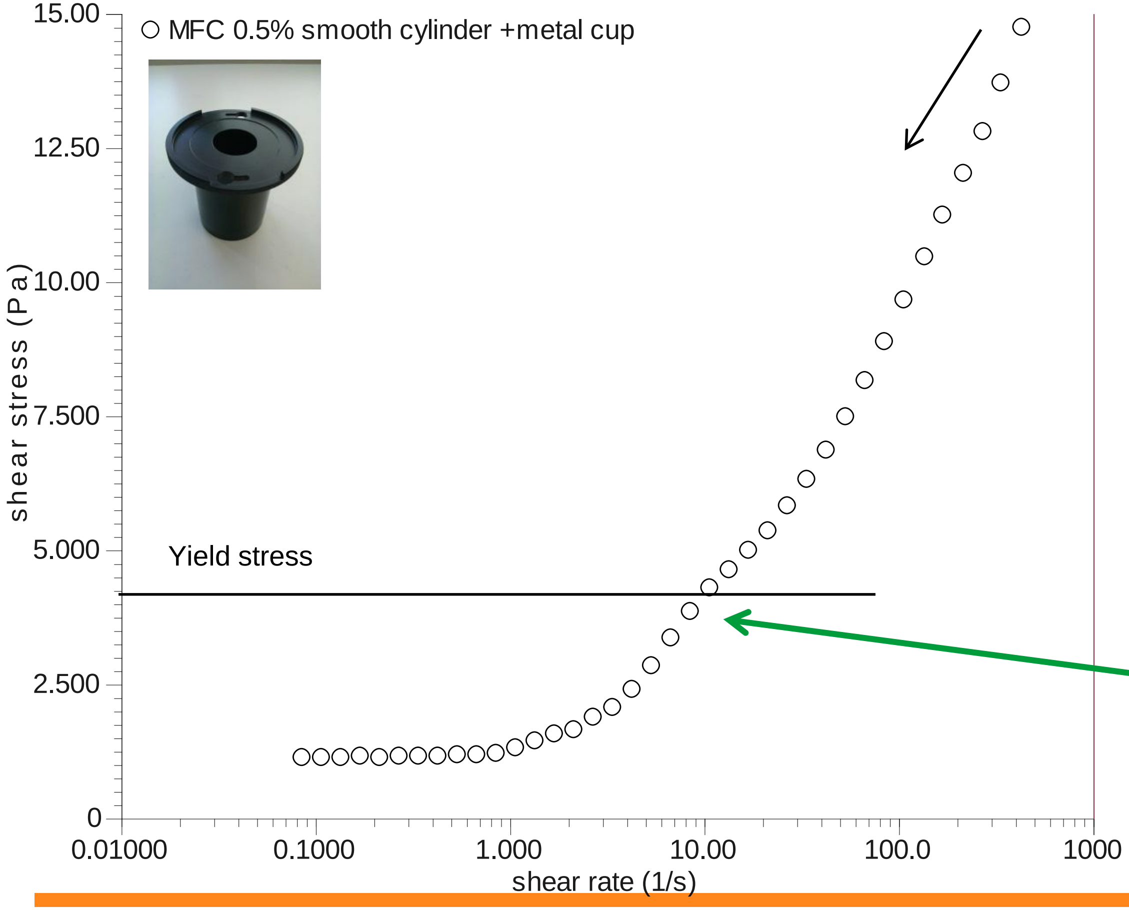
W.K.J. Mosse, D.V. Boger, G. Garnier, Avoiding slip in pulp suspension rheometry, J Rheol, 56, 1517 (2012)

Stress ramp
0.01…10000 microNm
MFC 0.5%

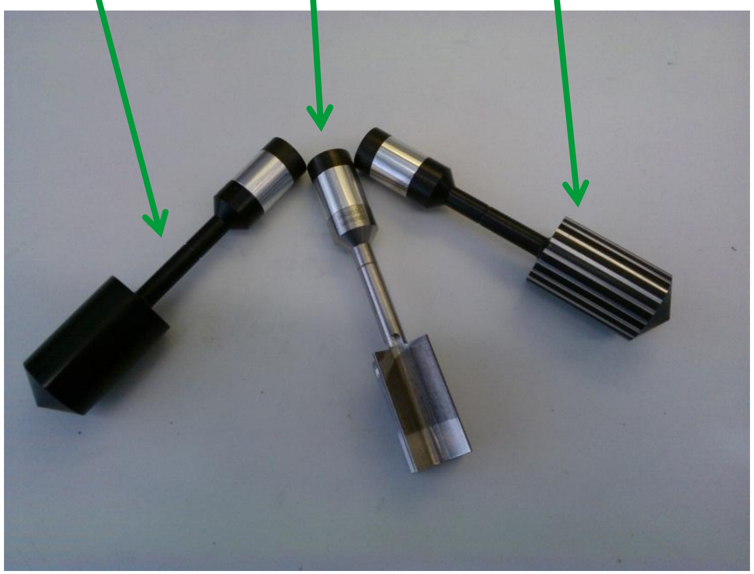


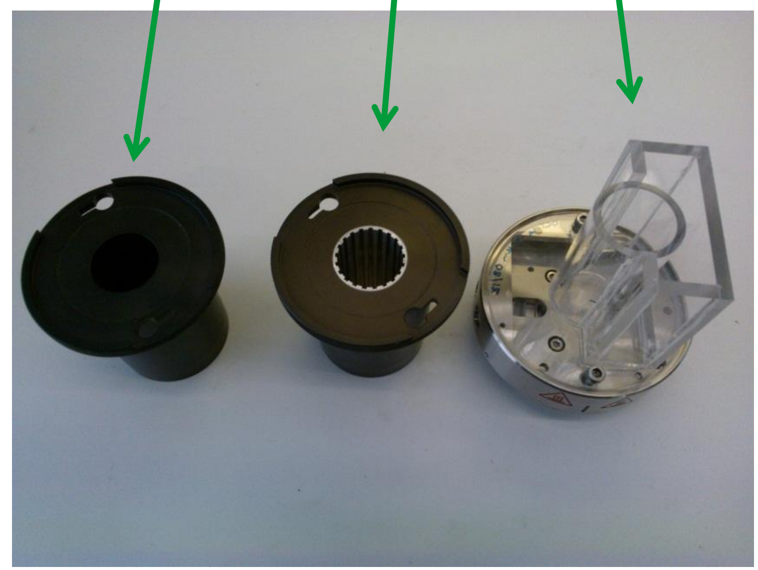
B. Derakhshandeh, S.G. Hatzikiriakos, C.P.J. Bennington, The apparent yield stress of fiber suspensions, J Rheol, 54, 1137 (2010)

Below yield stress the flocs start to attach to each other

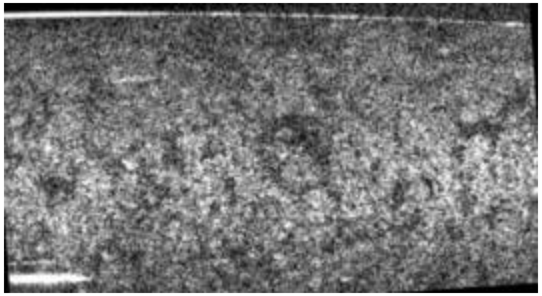


Can we avoid depletion by rough surfaces?

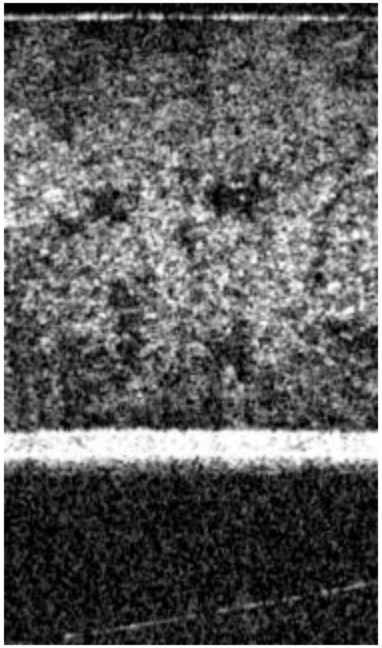




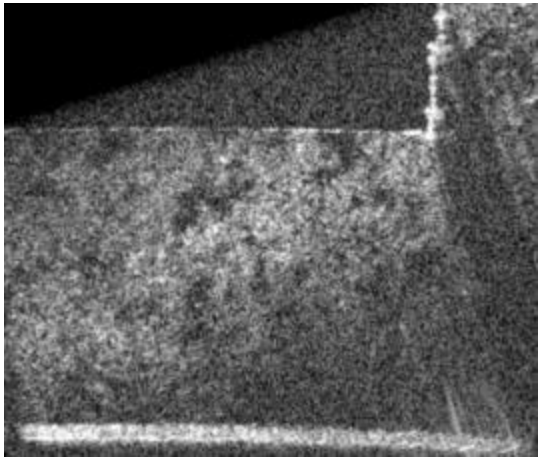
We could not avoid depletion completely



Vaned rotor and smooth cup



Grooved cylinder and smooth cup

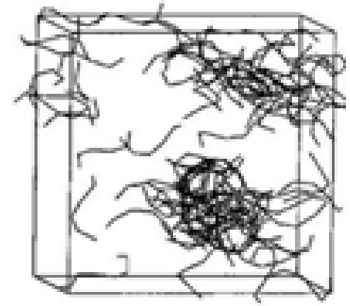


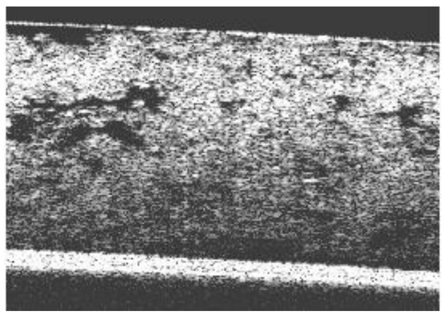
Grooved cylinder and cup

Videos by Sanna Haavisto

Conclusions

Rheology of MFC and other fiber materials is challenging to measure due to flocculation, wall depletion and shear banding (something else?)

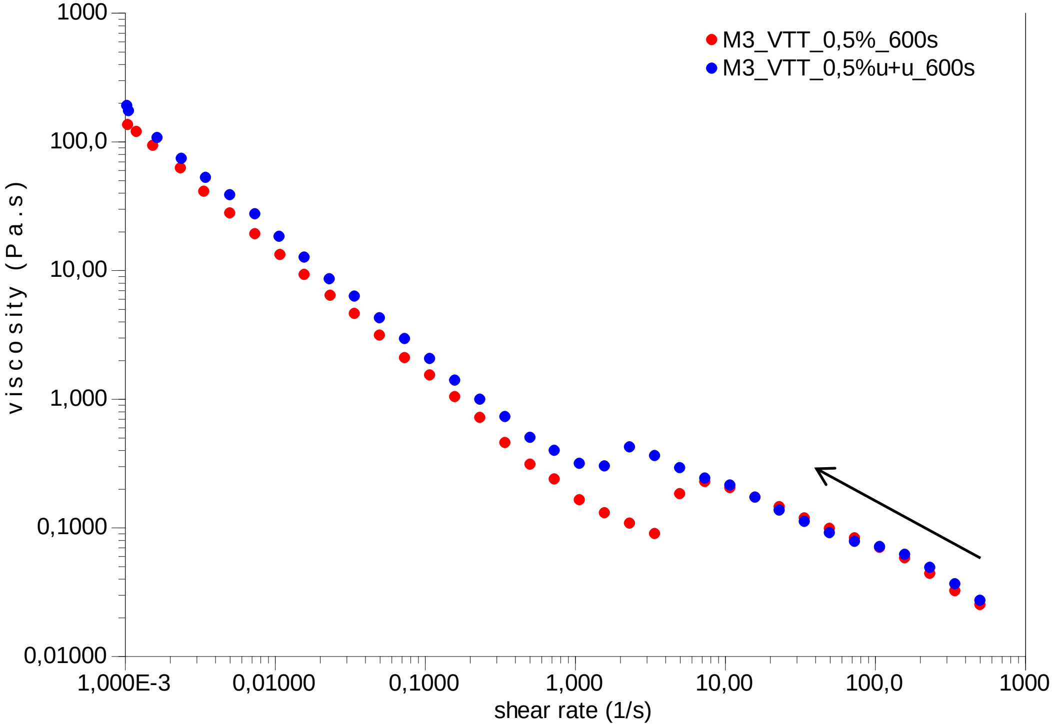




We have used photographing and OCT imaging to detect the structure and flow profile in the concentric cylinders geometry

In addition, we have determined yield stress in the ”infinite” cup. This method cannot be used for flow curve or oscillation measurements.

Flow curves with grooved cylinders



- The bend occurs ”later” in the measurement