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In-situ characterisation of fouling on membrane surfaces

- Fluid dynamic gauging

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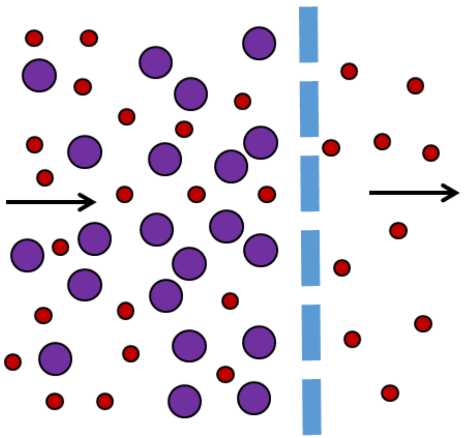
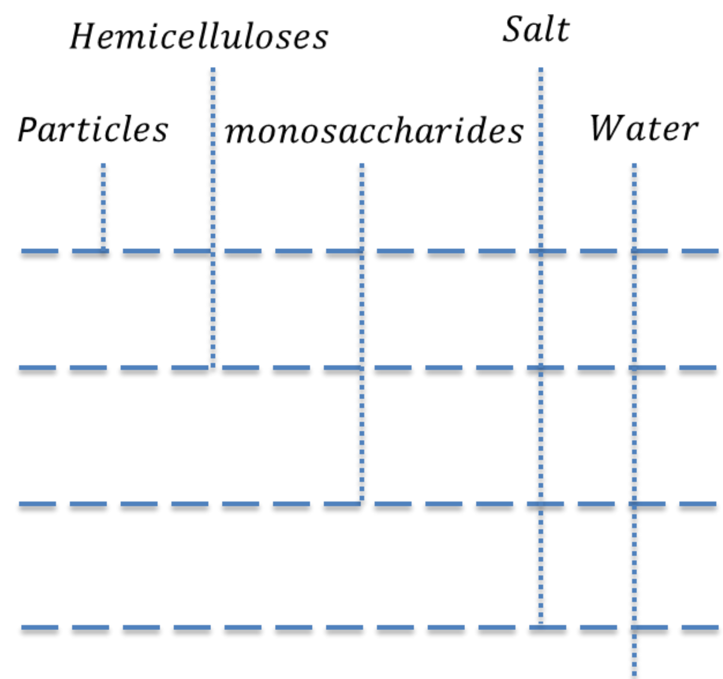
Membrane separation and fractionation





Microfiltration (MF)

Ultrafiltration (UF)

Nanofiltration (NF)

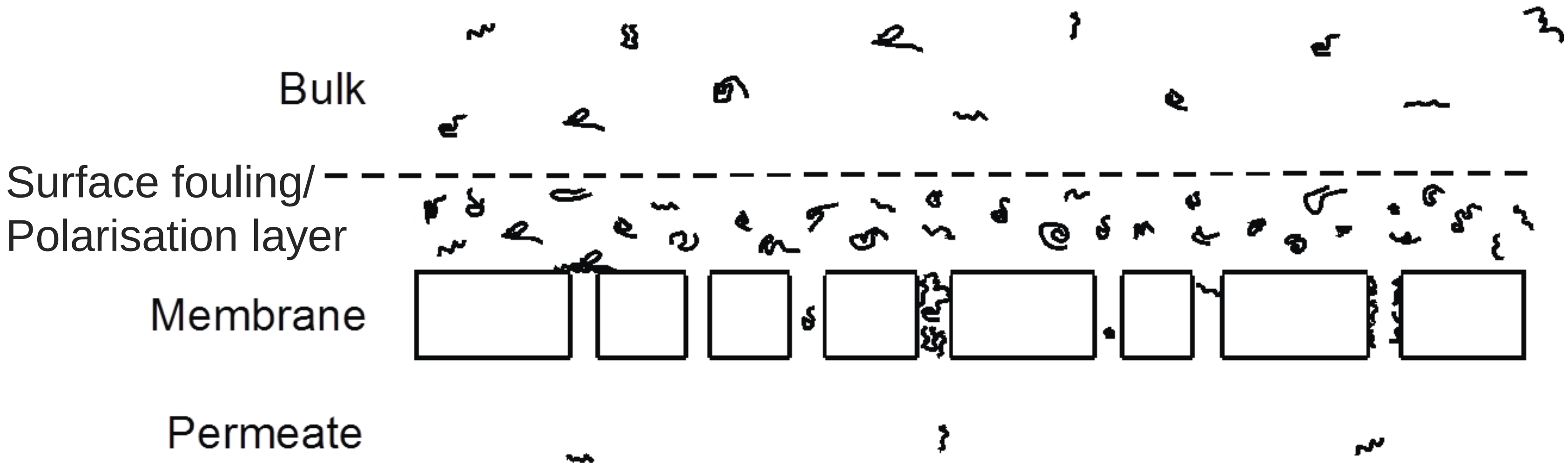
Reverse osmosis (RO)

Membrane filtration, Biorefinery

- Purification and concentration of cellulose nanocrystals/fibrils
- Concentration and fractionation/purification of extracted hemicelluloses
- Lignin separation and fractionation from black liquor
- …

Fouling

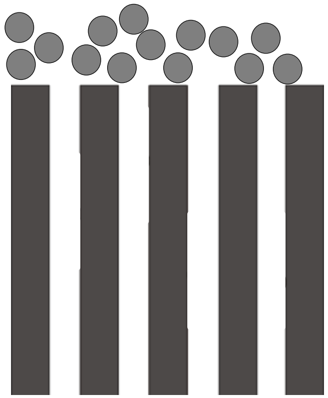
Fouling is one of the main challenges during membrane operations, where fouling will decrease production rate and may alter selectivity.



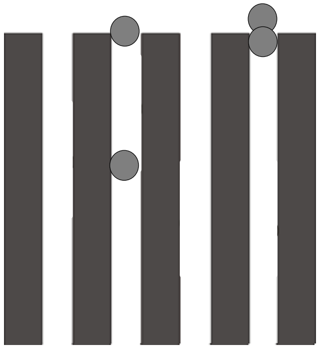
Minimise fouling

- Hydrodynamic optimisation of the membrane module (shear counteracts fouling)
- Pre-treatment of the feed
- Membrane surface modifications
- Membrane cleaning

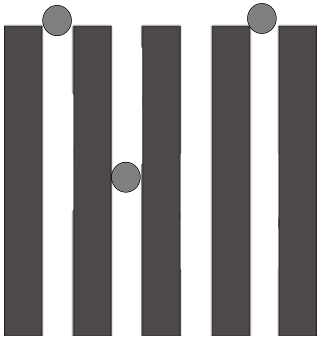
Fouling



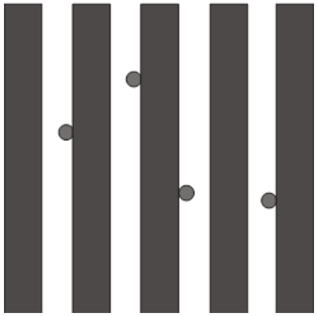
The cake blocking case.



The intermediate pore blocking case.



The complete pore blocking case.



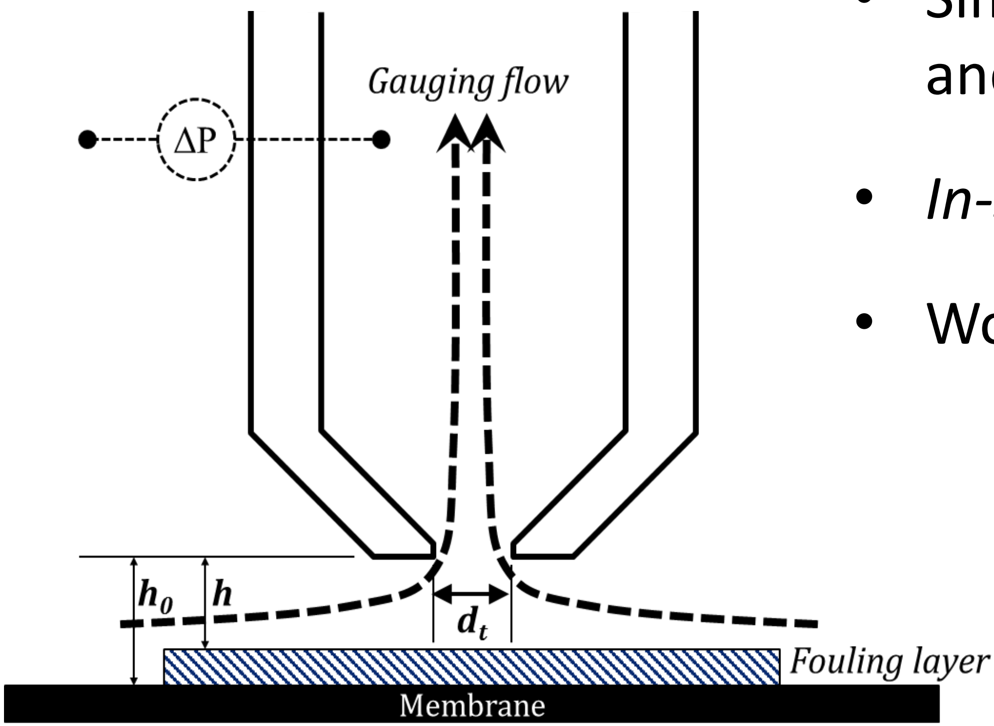
The standard pore blocking case.

Type	Form	C_i
Cake filtration	$\frac{d^2t}{dV^2} = C_i$	$\frac{\mu\alpha_{av}c}{A^2 \Delta P}$
Intermediate	$\frac{d^2t}{dV^2} = C_i\left(\frac{dt}{dV}\right)^1$	$\frac{\sigma}{A}$
Standard	$\frac{d^2t}{dV^2} = C_i\left(\frac{dt}{dV}\right)^{3/2}$	$\frac{2c}{\rho_s L_m}\left(\frac{\Delta P}{\mu R_m A}\right)^{1/2}$
Complete blocking	$\frac{d^2t}{dV^2} = C_i\left(\frac{dt}{dV}\right)^2$	$\frac{\Delta P}{\mu R_m}\sigma$

Investigation of surface fouling thickness

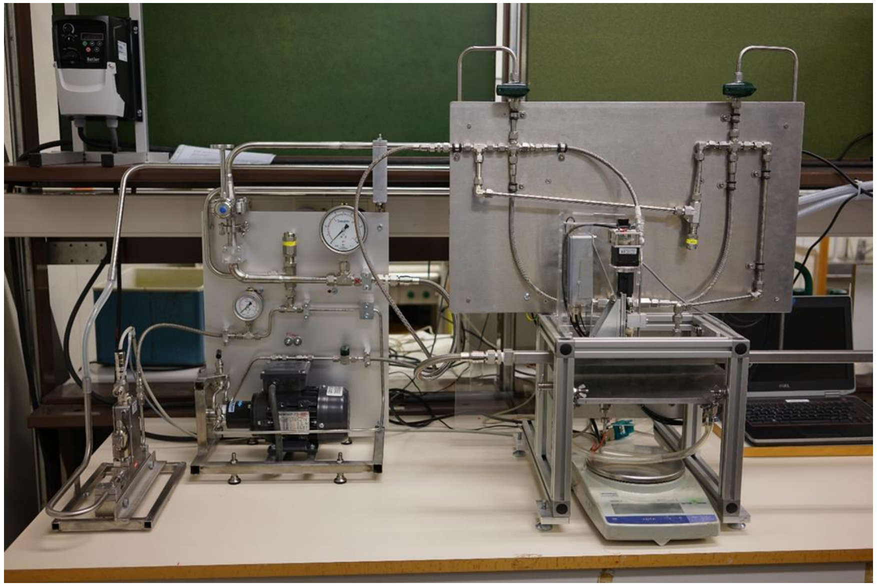
- Direct observation
- Laser Triangulometry
- Ultrasonic Time-Domain Reflectometry
- MRI

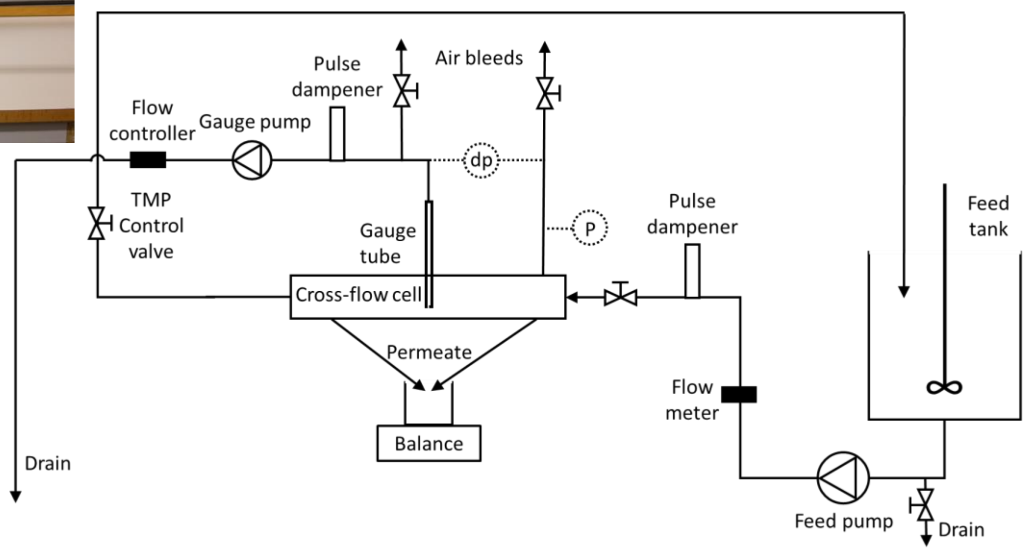
Fluid Dynamic Gauging



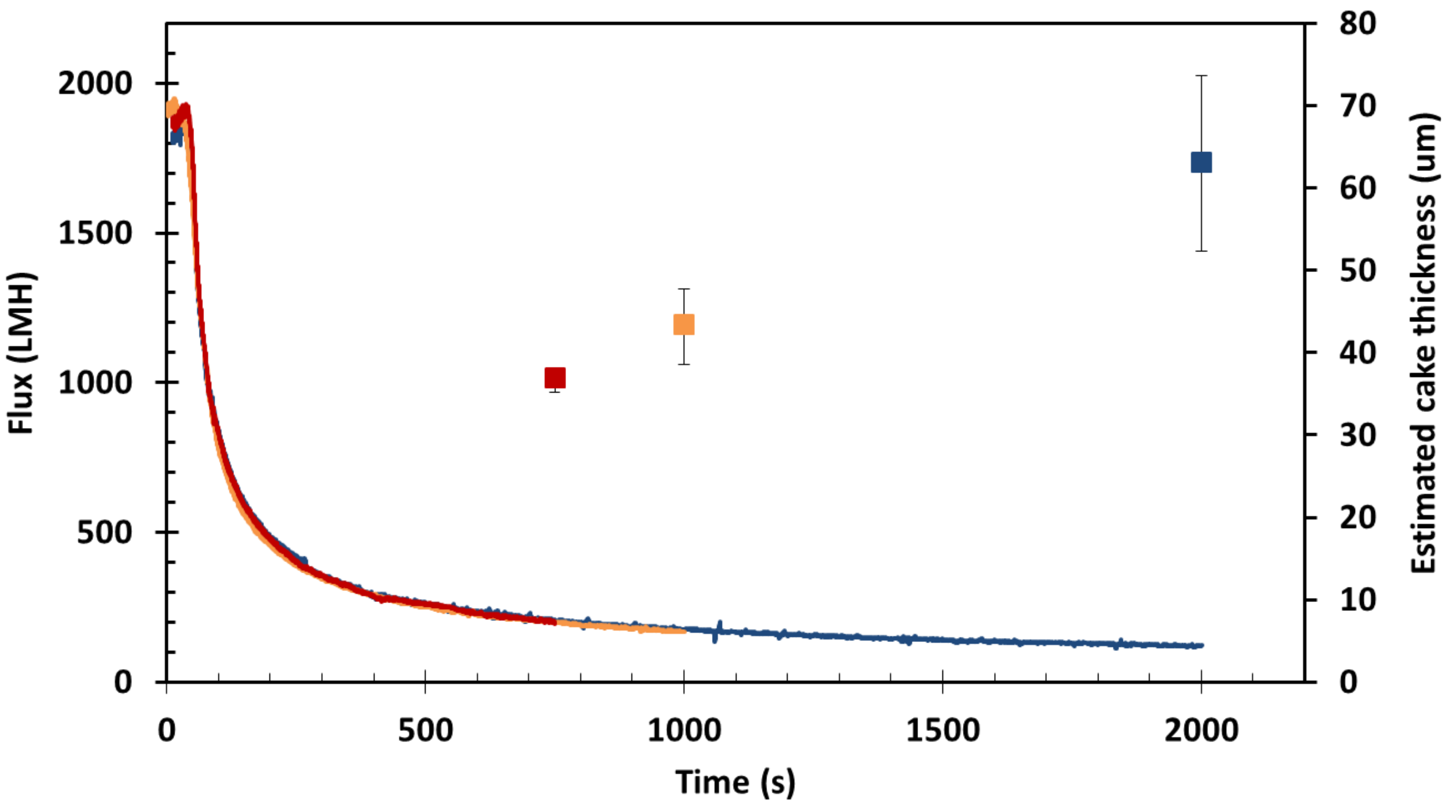
- Simultaneous strength testing and thickness measurements
- *In-situ* real-time measurements
- Works with opaque feeds

Unique equipment to investigate fouling





Crossflow filtration (MF: Lignin)



In Situ investigation of soft cake fouling layers using fluid dynamic gauging. T. Mattsson, W. J. T. Lewis, J. Y. M. Chew and M. R. Bird, *Food and Bioproducts Processing 93 2015, pp. 205-210*.

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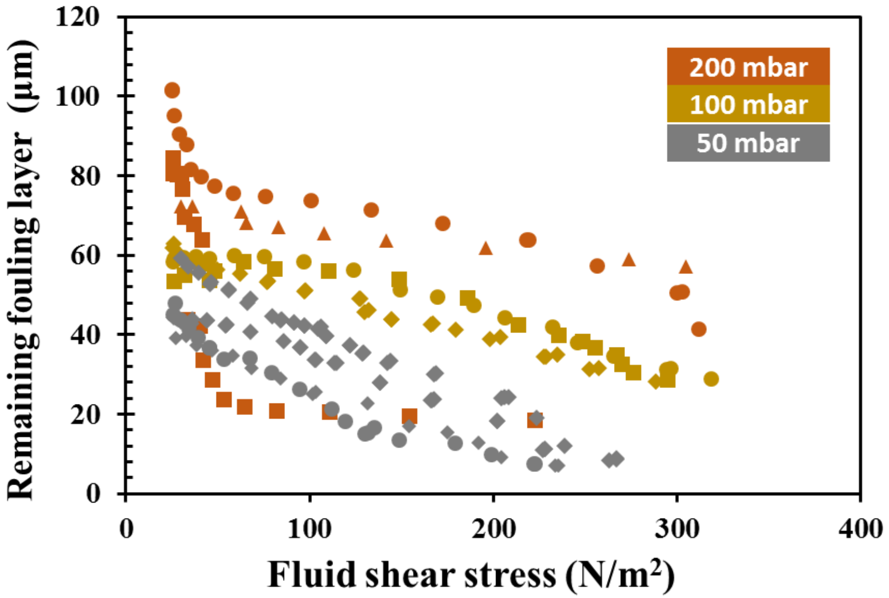
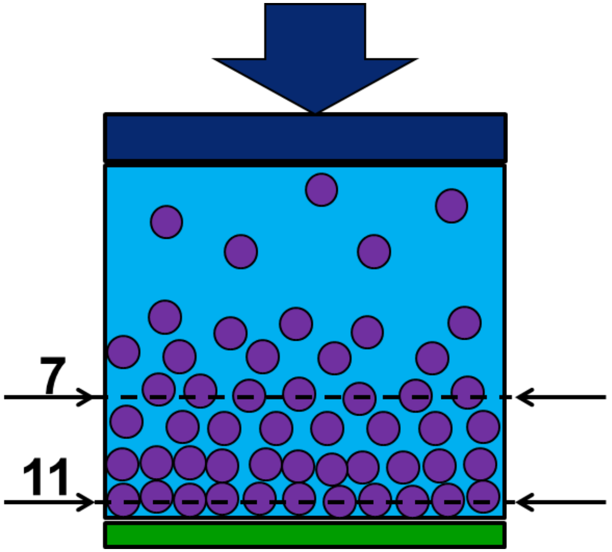
Removal and cohesive strength (MF: Lignin)

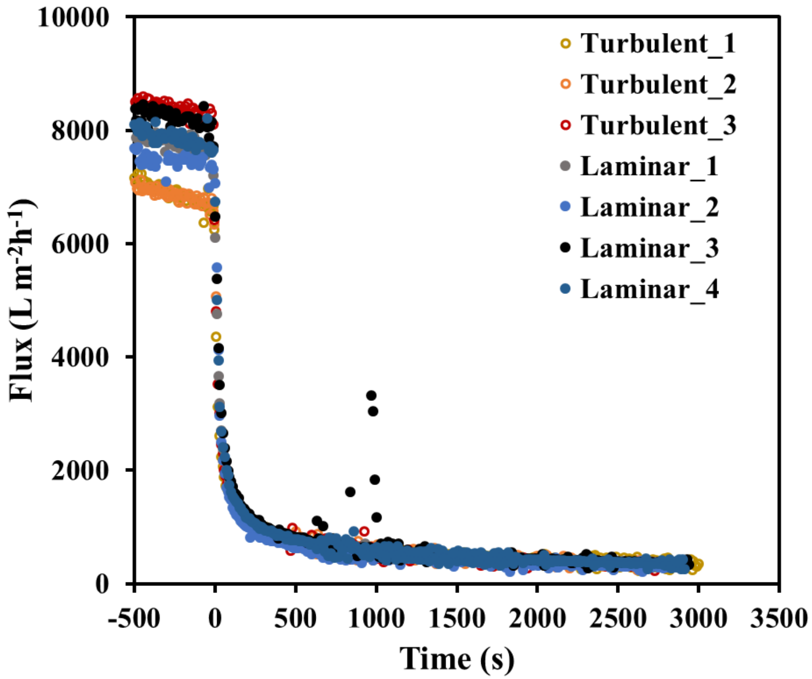


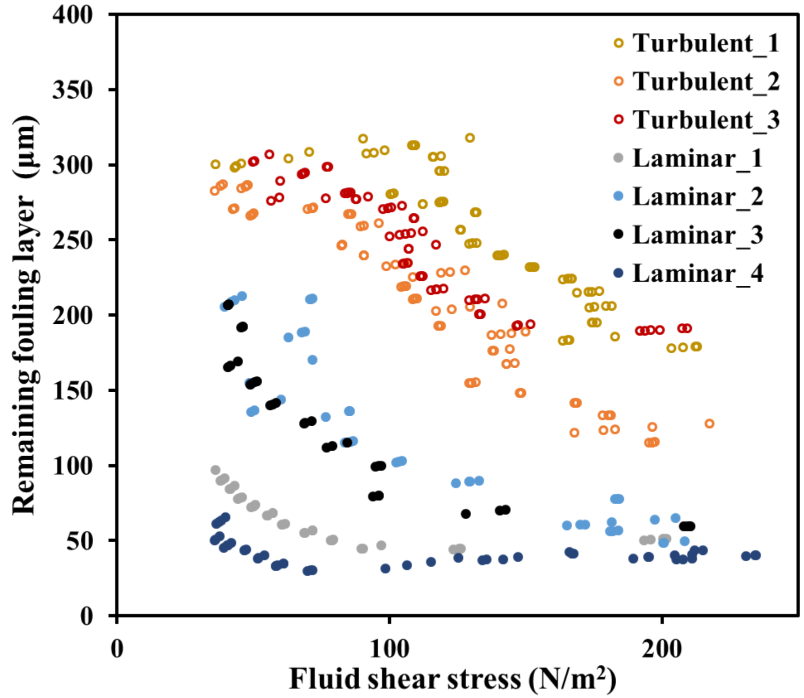
Compressible fouling layer:



The use of fluid dynamic gauging in investigating the thickness and cohesive strength of cake fouling layers formed during cross-flow microfiltration. T. Mattsson, W. J. T. Lewis, J. Y. M. Chew and M. R. Bird. *Separation and Purification Technology, 198, 2018*

Turbulent vs laminar crossflow (MCC)





Estimated remaining fouling layer thickness vs applied shear stress after 1000s of crossflow filtration.

	Laminar flow					Turbulent flow				
	1	2	3	4	Mean	1	2	3	4	mean
Surface weight (kg·m^{-2})	0.139	0.135	0.133	0.128	**0.134**	0.113	0.116	0.118	0.121	**0.117**

Effect of Crossflow Regime on the Deposit and Cohesive Strength of Membrane Surface Fouling layers. M. Zhou, T. Mattsson.
Food and Bioproducts Processing 115, 2019. DOI: 10.1016/j.fbp.2019.03.013

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Conclusions

- A higher transmembrane pressure resulted in lignin fouling layers with higher cohesive strengths.
- For the MCC model system a higher crossflow velocity resulted in less deposited material on the membrane but higher cohesive strength of the fouling layer.
- **FDG is a useful tool in characterising the strength properties and removal behaviour of membrane surface fouling**

Applications

- These fouling characteristics lays a foundation for mechanistic understanding of the fouling behaviour which can be used to enable design of cost efficient and selective separation processes by:

- Develop antifouling and membrane cleaning strategies
- Optimise crossflow velocity (the main energy demand during Micro- and Ultrafiltration)
- Guide membrane selection

Thanks for your attention!
Questions?