2016 Howard See Future Rheologist Travel Award

Research details:

Recipient:	Samuel Skinner
Supervisors:	Professor Peter Scales, Dr Anthony Stickland
Organisation:	Particulate Fluids Processing Centre, The University of Melbourne

Summary

Thanks to the Howard See Future Rheologist Travel Award, I was fortunate enough to present my research at the FILTECH 2016 conference in Cologne, Germany. My presentation was titled, 'Compressive rheology of biofouling: application to membrane bioreactors', in which accurate filtration modelling was applied to optimise the operation of membrane bioreactors used for water recycling. This work was presented in the session on Fouling and Ceramic Membranes. The post-presentation conversations with attendees from companies such as Grundfos were interesting, and focused on the importance of shear rheology during membrane cleaning.

This conference was also attended by my supervisor, Dr Anthony Stickland, who gave a fantastic presentation on 'Fast or slow filtering suspensions - A general approach to optimizing constant pressure batch filtration'. Another colleague at the Particulate Fluids Processing Centre, Eric Hoefgen also gave a terrific talk on 'Superposition of compression and shear in filtration'. Both of their presentations were personal highlights of the conference.

Conference details:

Title:	FILTECH 2016
Organiser(s):	Dr. Harald Anlauf, Prof. Eberhard Schmidt
Location:	Cologne, Germany
Dates:	October 11-13, 2016
FILTECH is the largest filtration event worldwide with 180 technical papers being presented covering topics on membrane processes, solid-liquid separation and interfacial rheology. It is a globally acknowledged platform for scientific research on filtration and separation technologies.	

Conference paper details:

Conference paper title:

Compressive rheology of biofouling: application to membrane bioreactors

Conference paper authors:

S.J. Skinner, A.D. Stickland, P.J. Scales

Conference paper abstract:

The operation of filtration membranes in membrane bioreactors (MBR) is severely affected by the formation of a bio-fouling layer that causes rapid increase in transmembrane pressure and results in frequent cleaning cycles. In many cases, the increase in transmembrane pressure has been inaccurately attributed to particulate fouling within the membrane. However, the fouling layer or filter cake that builds up from wastewater treatment sludge is highly compressible, thus any model of filtration in a MBR must properly account for compression of the suspension network structure within the filter cake.

The compressive rheology approach based on the theoretical framework developed by Buscall and White (1987) implicitly accounts for this compression by considering only local material properties (permeability and compressibility). We examine the compressive rheology of the fouling layer that is external to the filter membrane. A one-dimensional model (depicted in Fig. 1) based on the piston-driven filtration model of Landman et al. (1991) is proposed. The model can be used to predict the rise in transmembrane pressure necessary to maintain constant flux. The fouling layer dewatering properties required for the model were obtained using simple laboratory-based centrifuge and constant pressure filtration tests. The model was compared to pilot-plant MBR data. Optimisation of cycle times, flux rates, maximum operating pressures and other operating parameters are performed using this model.

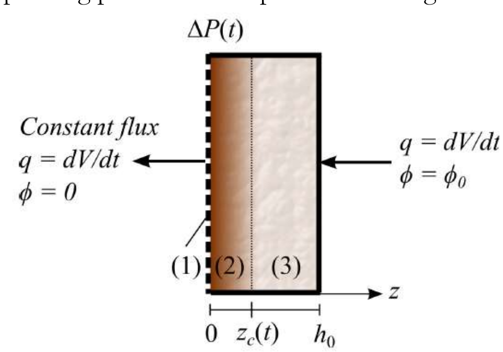

Fig. 1: Schematic of one-dimensional filtration in a MBR under constant flux q operation with a feed volume fraction ϕ_0 below the gel point ϕ_g. The transmembrane pressure $\Delta P(t)$ and fouling layer height $z_c(t)$ increase with time t. Region (1): membrane, $z = 0$; Region (2): fouling layer, $0 < z < z_c(t)$; Region (3): suspension at initial concentration, $z_c(t) < z < h_0$. At $z_c(t)$, $P_s = 0$ and $\phi = \phi_g$.

Rheological significance of work:

This work used compressive rheology to account for the fouling behaviour observed in advanced water treatment plants. These plants typically use membrane bioreactors to produce high quality water. The operation of these devices is severely inhibited by a compressible fouling layer on the filter membrane. After a period of operation, the applied pressure rapidly increases in order to maintain constant flux, triggering the need for frequent cleaning cycles. This rapid "jump" in pressure has been described using many different models that fail to consider the compression of the filter cake. This work shows using compressive rheology that this sudden increase in pressure is predicted for consolidating fouling layers. This allows for optimisation of the design and operation of membrane bioreactor design.

During this travel, I also presented on a centrifugal method for determining the shear and compressive strength of colloidal suspensions. This method corrects for the influence of the sample tube walls using an approach based on Lester et al. (2015). The work was presented at the International Workshop Dispersion Analysis and Materials Testing 2016, Berlin, Germany, September 26-27. A second presentation was given at this workshop on the use of compressive rheology to characterise the dewatering behaviour of sewage sludges.

References:

Buscall, R.; White, L.R. *J. Chem. Soc., Faraday Trans. I* **1987**, *83* (3), 873-891.

Landman, K.A.; Sirakoff, C.; White, L.R. *Phy. Fluids A* **1991**, *3* (6), 1495-1509.

Lester, D.R., Buscall, R., Stickland, A.D., Scales. P.J. *J. Rheol.* **2014**, *58* (5), 1247-1276.

Further research details:

Institution:	The University of Melbourne
Degree:	Ph.D.

My Ph.D. research involved investigating the dewatering properties of wastewater treatment sludges, and biofouling layers in membrane bioreactors. An experimental and data analysis methodology was developed that unified existing procedures for lab-scale filtration, centrifugation and gravity settling tests. This unified dewaterability characterisation methodology was used to quantitatively compare fifteen wastewater sludge samples. The comparison highlighted a correlation between lower volatile suspended solids and improved filterability. Further modelling of the extreme compressibility of biofouling layers has provided insights into optimisation of water recycling.