Hydrodynamic Techniques for Fouling Control in Membrane Systems

**Torino, 30/06/2022**

**PhD student: Bert Roberto**

**Supervisor: Prof. Costantino Manes**

**Co-Supervisor: Prof. Alberto Tiraferri**

# Doctoral dissertation: Hydrodynamic Techniques for Fouling Control in Membrane Systems: short dissertation

Fouling due to particle deposition either on the membrane surface or within the porous structure is the most adverse phenomenon in membrane-based separation systems. It causes an increase in both the hydraulic resistance and osmotic pressure at the feed-membrane interface leading to flux and selectivity reduction over time. Since this phenomenon is unavoidable, control approaches that minimise process complexity and operational costs are required to mitigate its effects. To this end, pulsed-hydrodynamics methods have proved to be cost-effective and easily implementable solutions that can improve the membrane's performance and durability. However, to fully understand and hence appropriately exploit such effects, it is necessary to understand the underpinning flow processes. Towards this end, in this work, we propose and validate a new module-scale laboratory facility to investigate, at very well-controlled flow conditions, both steady and pulsating flow behaviours.

A series of filtration experiments and flow measurements through laser diagnostic techniques (Particle Image Velocimetry and Laser Doppler Anemometry) were performed under flow-dynamics conditions typically encountered in membrane processes to shed light on the following aspects: (1) assess the effects of permeate flux (i.e. in fluid dynamics jargon “wall suction”) on the velocity statistics and turbulent structure of turbulent (low Reynolds number) channel flows; (2) explore the extent to which pulsating flows can mitigate fouling over a range of wave amplitudes and frequencies of the pulsation; (3) explain the effects related to fouling mitigation and enhancement of permeate flux using non-dimensional quantities to provide results of general validity.

As far as point 1 is concerned, results indicate that one-point velocity statistics in channel flows with suction collapse very well when scaled with the maximum velocity and channel half height. The comparison of the main velocity statistics for the benchmark smooth-wall condition and those obtained for different wall-suction flows indicate that suction tends to suppress turbulence independently of the suction rate. Such a suppression is consistent with an observed reduction in turbulent kinetic energy production while dissipation remain unaltered by suction. Interestingly (but strangely), despite this turbulence suppression, wall suction imposed rather weak variations in the turbulence structure as detected by means of quadrant analysis and two-point cross-correlation functions.

With regards to point 2 and 3, it was observed that the amplitude of the imposed wave has little effect on fouling mitigation, whereas frequency significantly controls both the increase in permeate and, consequently, in clogging reduction. It was speculated that this behaviour is controlled by a non-dimensional formulation of the pulsating frequency, which, according to the relevant literature, corresponds to conditions whereby the turbulence induced by the enhanced shear of the high-velocity phase of the pulsation, has the time to develop and propagate throughout the channel height. It is herein hypothesized that such enhanced turbulence helps particles escape from the near-wall flow region where they would be otherwise trapped or attracted by the suction flow.