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Rouae BEN DHIA[1], Denis MARTINAND[1], Nils TILTON[2]

[1] Aix-Marseille Univ., CNRS, Centrale Marseille, M2P2, France

[2] Mechanical Engineering, Colorado School of Mines, CO 80401, USA

Performances of filtration techniques are known to deteriorate with the accumulation of retained materials near the semi-permeable membranes. In the case of a solution considered here, the osmotic pressure induced by the concentration boundary layer forming near the membrane tends to cancel out the operating pressure driving the permeate flux accross the device. Dynamic filtration devices make use of hydrodynamic instabilities to mix the solution and abate the concentration boundary layer. However, no quantitative results exist to assess the couplings between mixing, osmotic pressure and instabilities, the effectiveness of dynamic filtration and how to optimize it.

This study adresses those couplings in a controled fashion by considering a Taylor-Couette cell, with a fixed outer cylinder and a rotating inner one. Moreover, the gap is filled with a solution and both cylinders are semi-permeable membranes totally rejecting the solute. Imposing an operating pressure accross the gap drives a radial in- or outflow and the transmembrane flow of pure solvent builds up a concentration boundary layer near the inner or outer cylinder. The osmotic pressure related to the concentration increase at the membrane then opposes the operating pressure and reduces the radial flow. For fixed operating conditions, a stationary state can be obtained analytically(figure 1a).

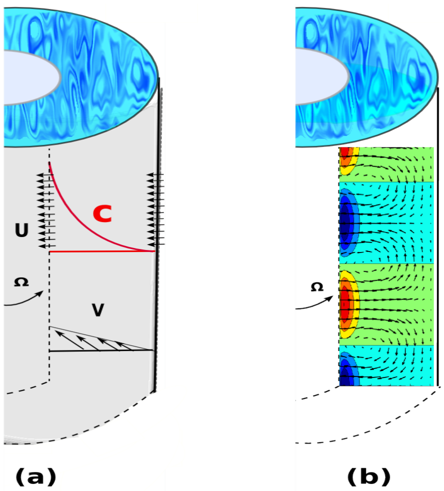

Figure 1: Figure of studied situation: a) Configuration and sketch of the base state (U,V : radial and azimuthal velocity components, C : concentration profile), b) Perturbation to this base state in a meridional plane.

As the rotation rate of the inner cylinder is increased, centrifugal instabilities emerge in the form of toroidal vortices. These instabilities are studied both analytically (figure 1b), using the previous stationary state as a base state, and numerically, using dedicated Direct Numerical Simulations implementing accurate boundary conditions for the transmembrane flow and pressure. Osmotic pressure is found to promote these centrifugal instabilities as a result of an original self-sustained mechanism coupling the advection of the concentration boundary layer by the vortices, molecular diffusion and osmotic pressure driving a transmembrane flow fostering the vortices. This mechanism can induce a substantial reduction of the critical rotation rate above which vortices are observed.
