

Supplementary information

for the manuscript

CFD-guided patterning of tubular ceramic membrane surface by stereolithography: Optimizing morphology at the mesoscale for improved hydrodynamic control of membrane fouling

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S1. k - ε turbulence model

To take into account turbulence effect, the standard k - ε turbulence model [1] was used. This model is robust, accuracy and widely used for many flow applications.

In addition to the conservation of momentum equation in the Navier-Stokes equation (Eq. (1)), the standard k - ε turbulence model, which is a semi-empirical model, is based on two additional transport equations for the turbulent kinetic energy k and for the turbulent dissipation rate ε as follow:

For the turbulent kinetic energy k (in $\text{m}^2.\text{s}^{-2}$):

$$\rho(\vec{v} \cdot \nabla k) = \nabla \cdot \left(\left(\eta + \frac{\eta_t}{\sigma_k} \right) \nabla k \right) + P_k - \rho \varepsilon \quad (\text{A1})$$

where P_k is the productive term of k due to the mean velocity gradients

$$P_k = \eta_t \left[\nabla \vec{v} : (\nabla \vec{v} + \nabla \vec{v}^T) - \frac{2}{3} (\nabla \cdot \vec{v})^2 \right] - \frac{2}{3} \rho k \nabla \cdot \vec{v} \quad (\text{A2})$$

And for the turbulent dissipation rate ε (in $\text{m}^2.\text{s}^{-3}$):

$$\rho(\vec{v} \cdot \nabla \varepsilon) = \nabla \cdot \left(\left(\eta + \frac{\eta_t}{\sigma_\varepsilon} \right) \nabla \varepsilon \right) + C_{\varepsilon 1} \frac{\varepsilon}{k} P_k - C_{\varepsilon 1} \rho \frac{\varepsilon^2}{k} \quad (\text{A3})$$

In this k - ε model, the turbulent viscosity μ_t (in $\text{m}^2.\text{s}^{-2}$) was modeled by combining k and ε using the equation:

$$\eta_t = \rho C_\eta \frac{k^2}{\varepsilon} \quad (\text{A4})$$

The standard k-ε model constants $C_{\varepsilon 1}$, $C_{\varepsilon 2}$, C_η , σ_k and σ_ε were issued from experimental data and could be adjusted. The default value of these constants are listed in Table S1.

Table S1. Model constants.

Constant	$C_{\varepsilon 1}$	$C_{\varepsilon 2}$	C_η	σ_k	σ_ε
Value	1.44	1.92	0.09	1.0	1.3

S2. Preparation of bacteria stock

To prepare the bacteria stock, one liter of PA01 (late exponential growth phase) with a final optical density (600 nm) of 1 were washed twice with 150 mM NaCl, (centrifuged for 10 min at 8000 rpm and 4 °C and resuspended by vortexing) and incubated in 4% formaldehyde solution for 2 h at room temperature to fix the bacteria. The cells were then washed three times with 150 mM NaCl (centrifuged for 10 min at 8000 rpm and 4 °C, and resuspended by vortexing) [20]. The fixed bacteria stock (pH 6) was stored at 4 °C for subsequent use.

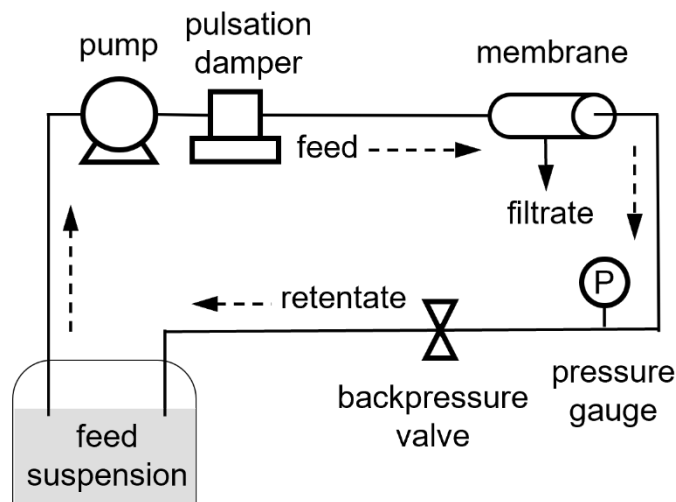
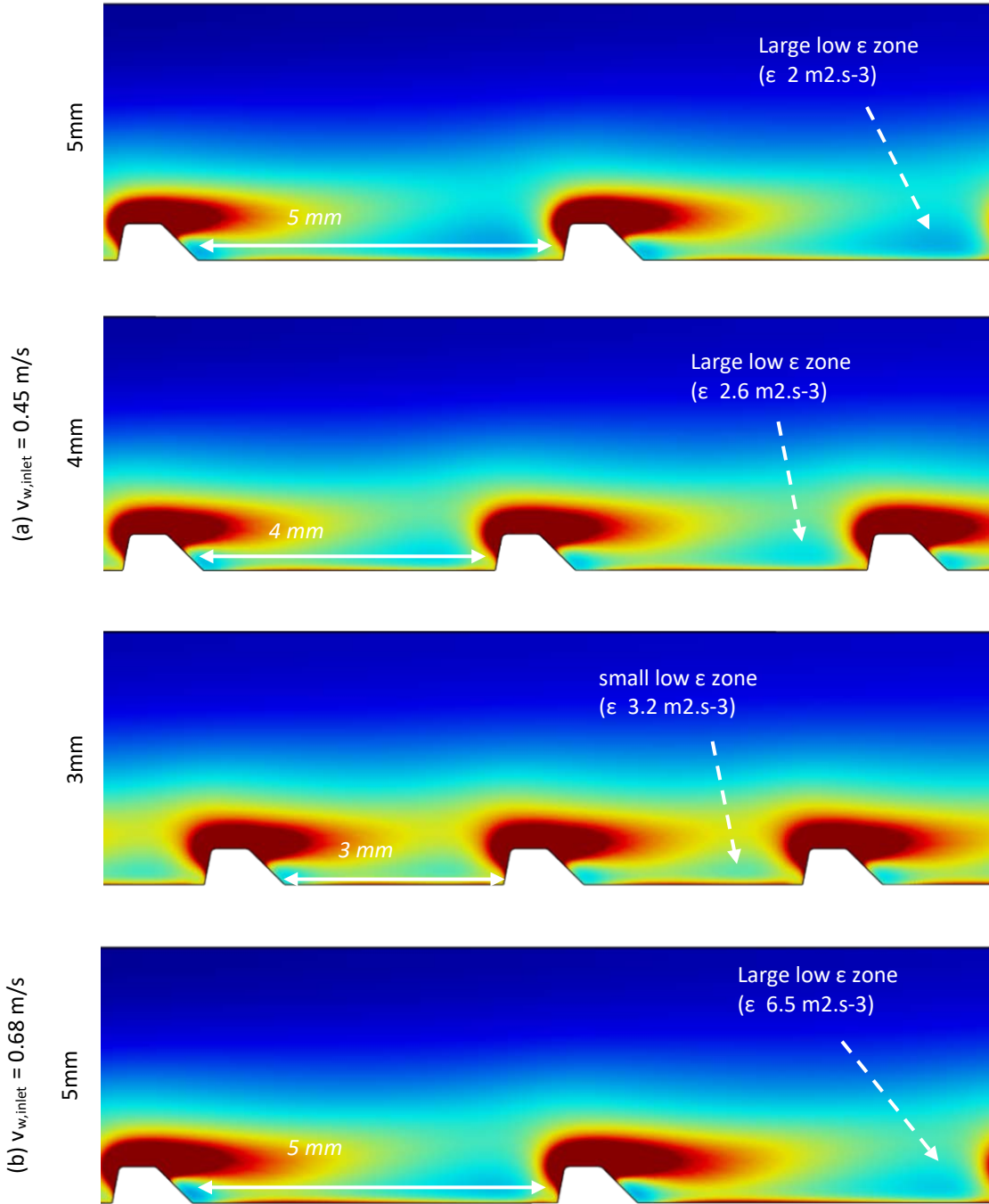


Figure S1. Schematic of the crossflow filtration setup. Dead-end filtration tests were performed using the same system but with the retentate outlet closed.



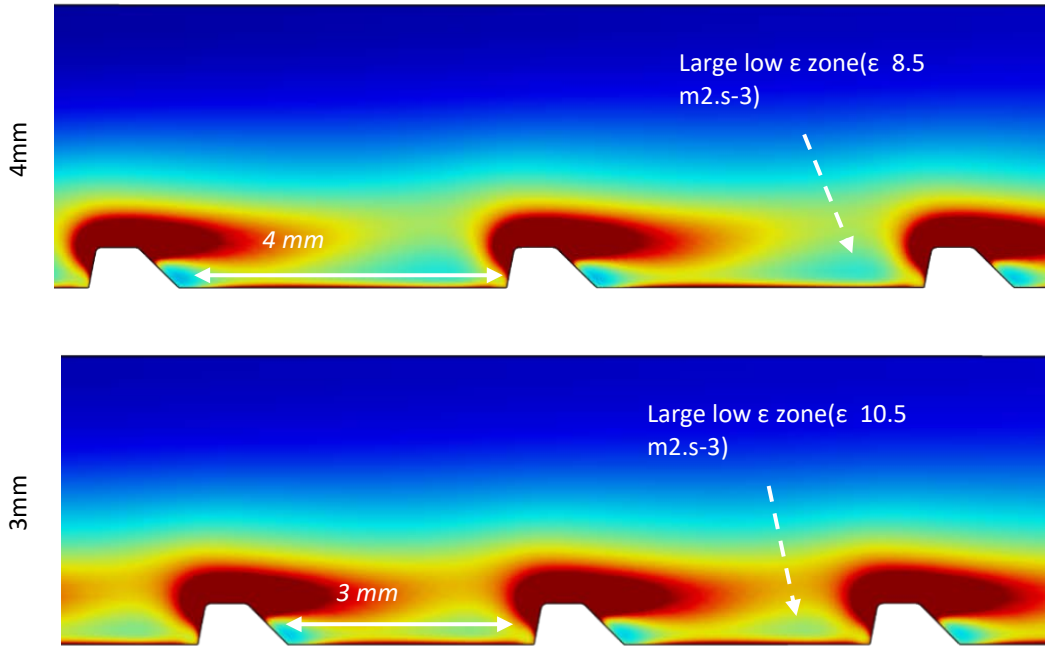


Figure S2. Mapping of ϵ inside the tubular membrane for 3 distances between the rings (3, 4 and 5 mm) and the two explored values of v_{inlet} : (a) 0.45 m s^{-1} ; (b) 0.68 m s^{-1} .

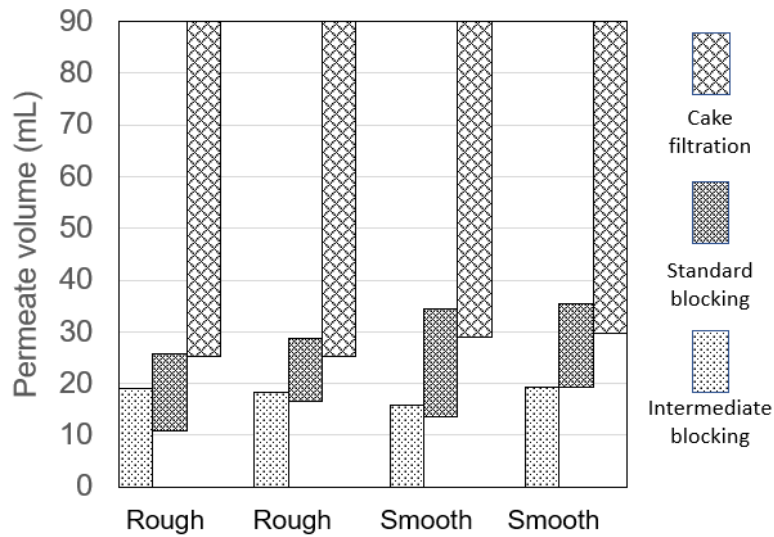


Figure S3. Evolution of fouling mechanism during dead-end filtration of bacterial suspensions by smooth and rough membranes.

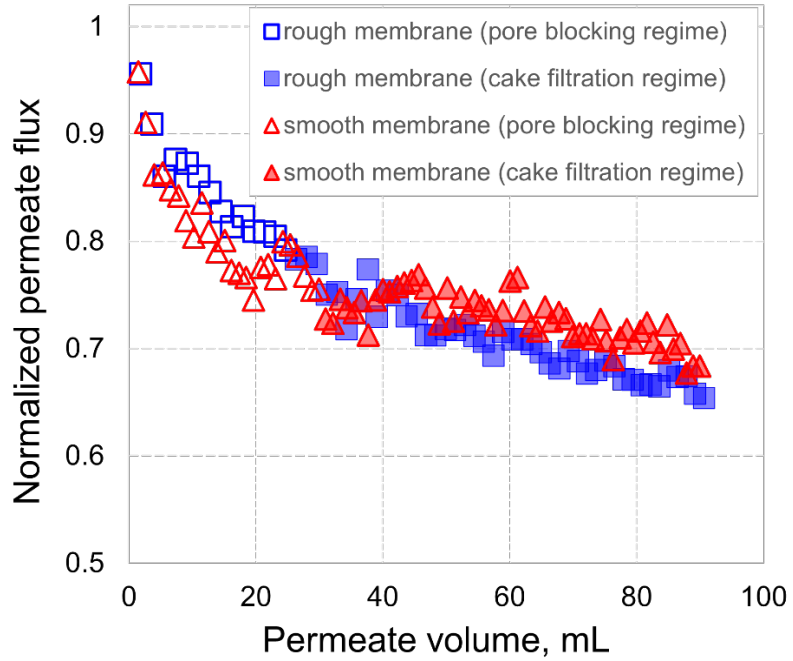


Figure S4. Normalized permeate flux recorded in dead-end filtration tests with smooth and rough membranes.

References

- [1] B.E. Launder, D.B. Spalding, The numerical computation of turbulent flows, *Comput. Method. Appl. Mechanics Eng.*, 3 (1974) 269-289.