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# Energy efficient aeration in a single low pressure Hollow Sheet Membrane Filtration Module

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## Introduction & Objectives

- Fouling is the main bottleneck of the widespread of MBR systems.
- Process hydrodynamics can decrease and/or control fouling.
  - by adding air and having a 2-phase flow.
- Hollow Sheet (HS) MBR (Alfa Laval) (Fig. 1)
  - Operates with low TMP (~0.03 bar) across the entire membrane surface (MS).
  - Permeate is drained from entire MS.
  - Advantages of low TMP are:
    - MS is less prone to fouling (longer service life)
    - Activated sludge (AS) passing across MS does NOT accumulate/stick to MS.
    - AS flows upwards between the membrane sheets while permeate passes through the MS.
- To ensures that AS circulates properly:
  - Air bubbles are used to create a two-phase cross-flow velocity
  - Bubbles generate scouring effect to remove particles that are attached to MS.

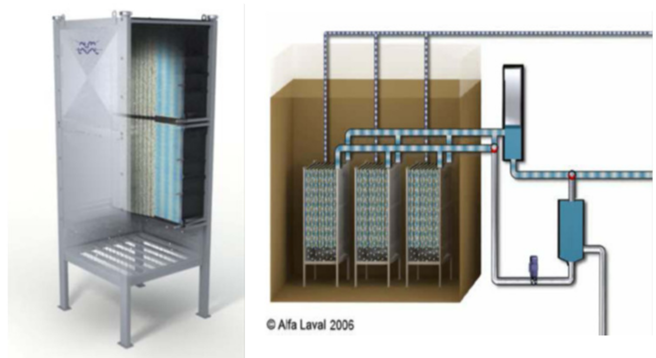


**Figure 1.** Alfa Laval MBR

## Methodology

### Velocity measurements

- Single filtration module which has 86 HS polyvinyl membranes (total MS of 154 m$^2$) (Fig. 2).
- Experiments were conducted at the Danish Hydraulic Institute (DHI) (Fig. 3).
- Experimental velocity measurements were obtained from micro-propellers (MP) between two HS membranes (Fig. 4).
- Air is introduced in reactor through 7 perforated pipes with 7 holes (4 mm) in each pipe.
- Air flow rate in the experiment was 55 and 83 m$^3$·h$^{-1}$ and CFD model was 37, 55 and 83 m$^3$·h$^{-1}$.

### CFD model (Fig. 5)

- Ansys CFX v13
- Mixture 2-phase model
- k-$\epsilon$ turbulence model

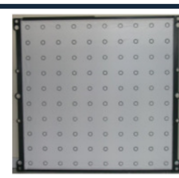

**Figure 2.** HS membrane

**Figure 3.** Experimental HS reactor and MP

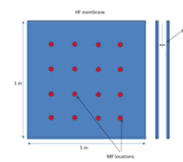

**Figure 4.** locations of the MP

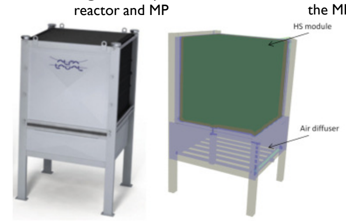


**Figure 5.** Real and virtual representation MBR module.

## Results and discussion

### Velocity measurements

- CFD velocity profiles for one HS membrane (Fig. 6).

| Air flow rate (m$^3$·h$^{-1}$) | Experimental (m·s$^{-1}$) | CFD (m·s$^{-1}$) | Error (%) |
|---|---|---|---|
| 37* | - | 0.198 ± 0.054 | - |
| 55 | 0.218 ± 0.051 | 0.242 ± 0.065 | 10.9 |
| 83 | 0.309 ± 0.067 | 0.292 ± 0.072 | 5.7 |

*Experimental measurements were not carried out at this air flow rate

- Air is well distributed within module and no pronounced dead zones were found (Fig. 7).
- A fairly good agreement between the experimental measurements and the CFD simulation regarding the magnitude of the velocity was achieved (error less than 11 %).
- CFD model enabled to provide insight on the velocity profiles and air distribution.

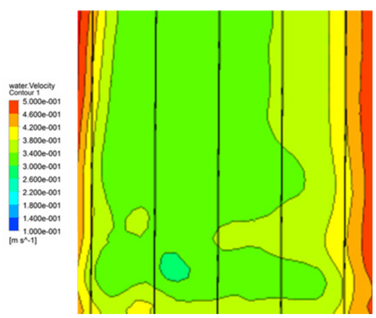

**Figure 6.** Contour plot of CFD velocities between filtration sheets at an air flow rate of 55 m$^3$·h$^{-1}$.

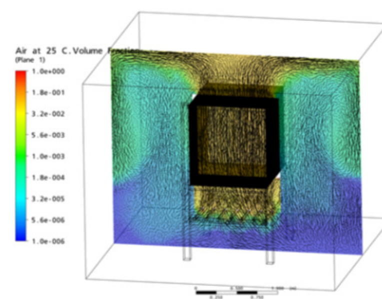

**Figure 7.** Air volume fraction and velocity vectors for a HS membrane filtration module

### Wall shear stress

- It was inferred from CFD simulation that values of the shear stress were accurate (Fig. 8).

| Air flow rate (m$^3$·h$^{-1}$) | CFD (Pa) |
|---|---|
| 37 | 0.196 ± 0.02 |
| 55 | 0.384 ± 0.02 |
| 83 | 0.464 ± 0.03 |

- Shear stresses on MS are evenly distributed.

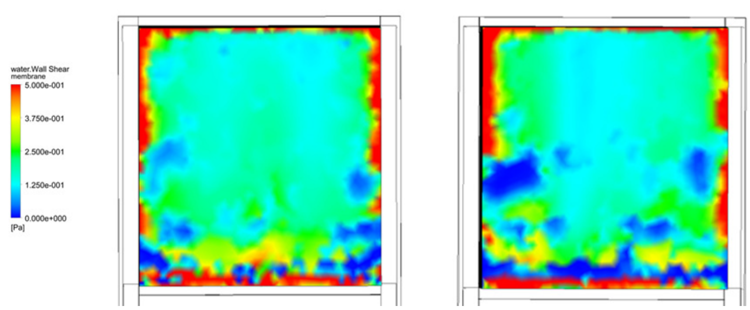

**Figure 8.** Shear stress profiles for the HS system for an air flow rate of 37 m$^3$·h$^{-1}$. Above diffuser holes (left) and between diffuser holes (right).

## Conclusions

- A proper validation of the CFD model was made in terms of velocity measurements using MP with water.
- An error less than 11 % was found between experimental measurements and CFD simulations in terms of velocity profiles.
- Wall shear stress was inferred from CFD simulations.
- Shear stress is homogeneously distributes over the HS MS



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