Energy Efficient Aeration in a Single Low Pressure Hollow Sheet Membrane Filtration Module
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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 ensure 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.

Methodology

Velocity measurements

• Single filtration module which has 86 HS polyvinyl membranes (total MS of 154 m²) (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 m³⋅h⁻¹ and CFD model was 37, 55 and 83 m³⋅h⁻¹.

CFD model (Fig. 5)

• Ansys CFX v13
• Mixture 2-phase model
• k-ε turbulence model

Results and discussion

Velocity measurements

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

<table>
<thead>
<tr>
<th>Air flow rate (m³⋅h⁻¹)</th>
<th>Experimental (m/s)</th>
<th>CFD (m/s)</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>0.198 ± 0.054</td>
<td>0.218 ± 0.051</td>
<td>10.9</td>
</tr>
<tr>
<td>55</td>
<td>0.242 ± 0.065</td>
<td>0.218 ± 0.051</td>
<td>10.9</td>
</tr>
<tr>
<td>83</td>
<td>0.292 ± 0.072</td>
<td>0.309 ± 0.067</td>
<td>5.7</td>
</tr>
</tbody>
</table>

*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.

Wall shear stress

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

<table>
<thead>
<tr>
<th>Air flow rate (m³⋅h⁻¹)</th>
<th>CFD (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>0.196 ± 0.02</td>
</tr>
<tr>
<td>55</td>
<td>0.384 ± 0.02</td>
</tr>
<tr>
<td>83</td>
<td>0.464 ± 0.03</td>
</tr>
</tbody>
</table>

• Shear stresses on MS are evenly distributed.

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.