Optimization of a hydrodynamic separator using a multiscale CFD approach

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1. Introduction

2. Objectives
3. Methods
4. Results
5. Conclusion
Stormwater pollution:
- plastic debris
- coarse sediments
- large particles

Hydrodynamic separator:
- structure used to remove gross pollutants from water
The CycloneSep®: the pilot of IMFS lab

h = 1 m; D_{screen} = 1 m; D_{ext} = 2 m
The CycloneSep®: the pilot of IMFS lab

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- **Objectives**

- **Methods**

- **Results**

- **Conclusion**

- **h = 1 m ; D_{screen} = 1 m ; D_{ext} = 2 m**
The CycloneSep®: the pilot of IMFS lab

\( h = 1 \text{ m} \); \( D_{\text{screen}} = 1 \text{ m} \); \( D_{\text{ext}} = 2 \text{ m} \)
The CycloneSep®: the pilot of IMFS lab

h = 1 m; D_{screen} = 1 m; D_{ext} = 2 m
The CycloneSep: large waste in rotation
1. Introduction

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Computational Fluid Dynamics: hydrodynamic visualization

- Storage tank
  - Dufresne et al. 2008

- Lamella settlers
  - Vazquez et al. 2008

- Hydrocyclone
  - Lee et al. 2010
Discretization of the domain
Discretization of the domain

fine mesh nearby the screen
Discretization of the domain:

discretization of the volume
Discretization of the domain

- fine mesh nearby the screen
- discretization of the volume

→ Difficulties in mesh generation
→ Too long computational time
Discretization of the domain

- fine mesh nearby the screen
  +

- discretization of the volume
  =

- Difficulties in mesh generation
- Too long computational time

Multiscale approach
2 Objectives
2 Objectives

Engineering

Optimization
2 Objectives

Engineering
Optimization

Research
Multiscale method
1. Introduction
2. Objectives

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4. Results
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Portion of the actual screen

Local phenomena

Porous screen

Global behaviour
### Methods

**Porous screen**

**Energy Loss**

**Hydrodynamic profile?**

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**Portion of the actual screen**

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Boundary conditions

Local Model:
Actual screen

\[ V_{\text{out}} - V_{\text{in}} \Rightarrow Q_{\text{screen}} \]
Estimation of the energy loss caused by the screen

\[ P = \int \int \rho gHV \, dS \]

\[ \Delta H = K \left( \frac{Q^2}{S^2} \right) \frac{1}{2g} \]
Boundary conditions

Global Model: Porous screen

\begin{itemize}
  \item \( \mathbf{V}_{\text{in}} \) impose the discharge
  \item \( \mathbf{P}_{\text{out}} \) impose the downstream water level
\end{itemize}
**Reproduction of the Energy loss in the global model**

- Source term in the CFD code:

\[
S_i = -\left( \frac{K}{\Delta m} \frac{1}{2} \rho \mathbf{u}_{mag} \mathbf{u}_i \right)
\]
1. Introduction
2. Objectives
3. Methods

4. Results
   • Validation of the method
   • Optimization

5. Conclusion
### Results

- **Comparison: CFD/ Measurements**

![Velocity field (mid screen)](image-url)
**Velocity fields**

**Experimental measurements**

**CFD**

Comparison of the velocity field for a flow rate equal to 25 L/s at z = 38 cm
**Comparison: CFD/Measurements**

- Velocity near the screen
- Velocity under the screen
- Discharge in circulation
- Inlet discharge
Global/local values:

<table>
<thead>
<tr>
<th></th>
<th>Discharge ratio</th>
<th>$V_{\text{grid}}$ (m/s)</th>
<th>$V_{\text{under_grid}}$ (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurements</td>
<td>10,1</td>
<td>0,73</td>
<td>0,76</td>
</tr>
<tr>
<td>CFD</td>
<td>10,1</td>
<td>0,84</td>
<td>0,82</td>
</tr>
<tr>
<td>Error</td>
<td>0,1%</td>
<td>15%</td>
<td>8%</td>
</tr>
</tbody>
</table>

*Comparison for a flow rate equal to 25 L/s*
Local Model

Global Model

Local phenomena

Global behaviour
CFD Optimization

Minimize the clog
CFD Optimization

Minimize the clog

Pressure effects near the apertures
CFD Optimization

Minimize the clog

Pressure effects near the apertures

Testing different parameters
- Shape comparison: expanded metal VS perforated screen

CycloneSep screen

ΔP = 250 Pa

Hexagonal holes

ΔP = 60 Pa

Circular holes

ΔP = 30 Pa
Shape comparison: influence of hole size

45° 25mm x 5.2mm

$\Delta P = 100 \text{ Pa}$

45° 17mm x 1.65mm

$\Delta P = 150 \text{ Pa}$
**Shape comparison**: influence of metal inclinaison

- 60° 17mm x 1,65mm
- 45° 17mm x 1,65mm

ΔP = 250 Pa

ΔP = 150 Pa
CFD Optimization

Minimize the clog

Control the hydrodynamic behaviour
**CFD Optimization**

- Minimize the clog
- Control the hydrodynamic behaviour
  - Maximize velocity near the screen
  - Minimize velocity under the screen
CFD Optimization

Minimize the clog

Control the hydrodynamic behaviour

Maximize velocity near the screen
Minimize velocity under the screen

Installation of singularities
Optimization of the device: \((Q=25\text{L/s})\)

6 deflectors
Optimization of the device: \((Q=25 \text{L/s})\)

- 6 deflectors
- Disk plate
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CFD multiscale approach is a good alternative to optimize a device at different scale.
THANK YOU FOR YOUR ATTENTION

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CFD simulations:

- 2 500 000 cells for the local model
- 1 200 000 cells for the global model
- Turbulence model: RSM
- Discretization scheme: 2\textsuperscript{nd} order
• Validation of the local model
  - $K_{\text{exp}} = 1700$
  - $K_{\text{cfd}} = 1900$

<table>
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<tr>
<th>Q (L/s)</th>
<th>$H_{\text{exp}}$ (m)</th>
<th>$H_{\text{cfd}}$ (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>0.028</td>
<td>0.017</td>
</tr>
<tr>
<td>25</td>
<td>0.054</td>
<td>0.55</td>
</tr>
<tr>
<td>50</td>
<td>0.203</td>
<td>0.225</td>
</tr>
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CycloneSep Trouville/Mer (France)