Computational Analysis on Multiphase Flow in a Vortex Separator as Intake Device for Sea Water

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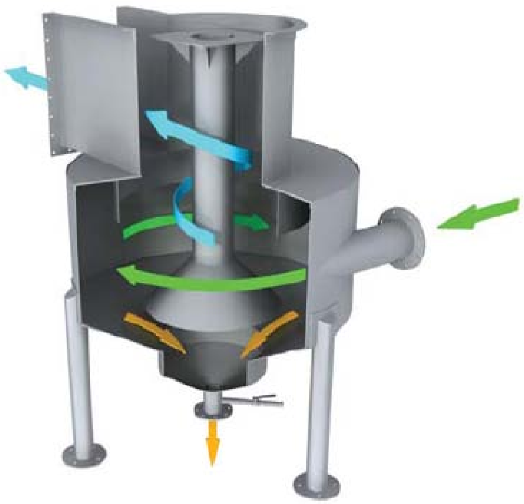

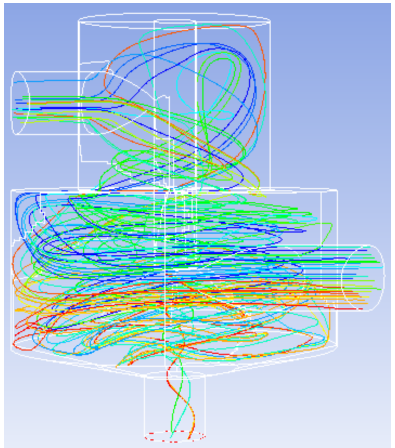

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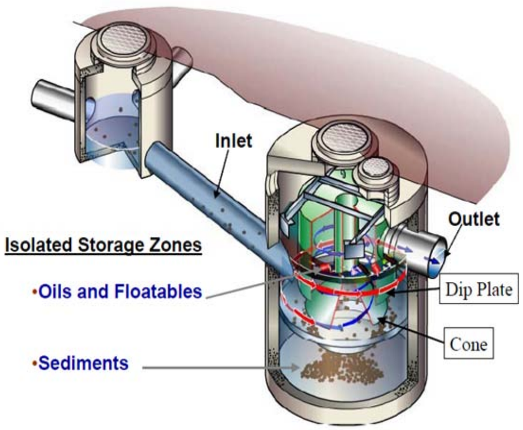
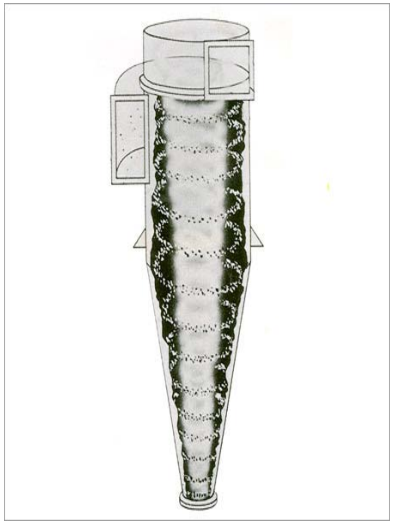
I. INTRODUCTION

Vortex Separator

Deep sea water intake system is under development, and vortex separator for separating particulate matter from the seawater is recommended.



Downstream Defender® HDVS



Bhaskar, Mineral Eng (2007)

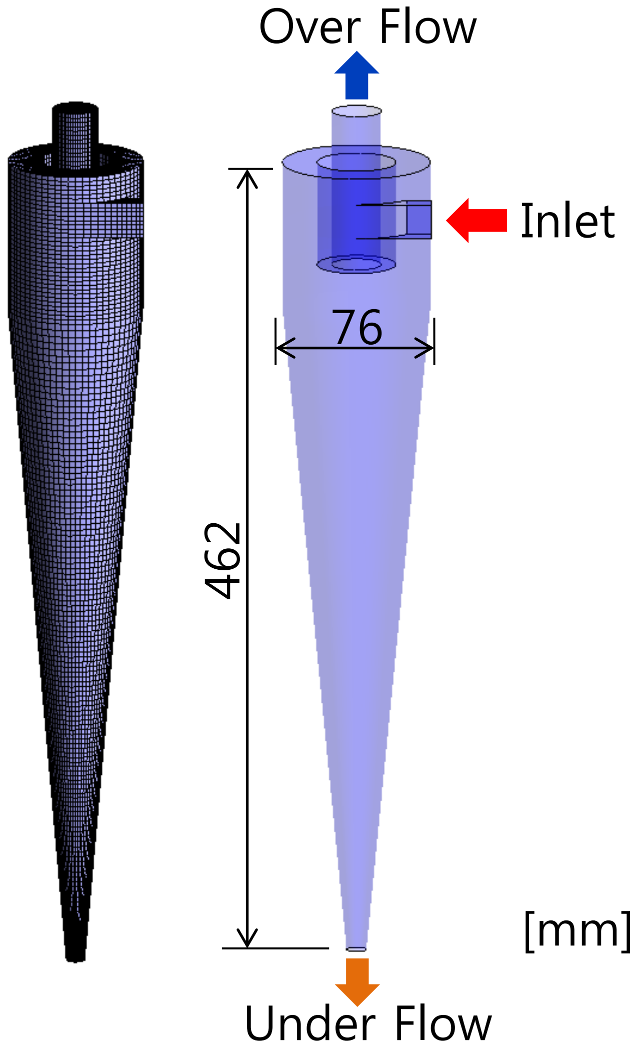
- Flow forced into tangential inlet under pressure causing flow to spin
- Pressure gradients within cyclone create two vortices, one inside the other, spinning in same direction but with opposite axial direction
- Density difference between water and solids causes water collect at axial core
- Dense phase exits at “underflow” & light phase exits at “overflow” adjacent to inlet

II. COMPUTATIONAL MODEL

- **Materials**
  Water Density : 998.2 kg/m3
  Particulate Density : 2300kg/m3
  Mass fraction of solid phase at inlet : 10%
  particle diameter : 10, 20, 30, 40μm

- **Boundary conditions**
  inlet : mass flow rate 1.3kg/s
  wall : no-slip

- **Two-Phase (Liquid-Solid), Granular Flow**
  Re = 31000 (Inlet Velocity, Diameter)



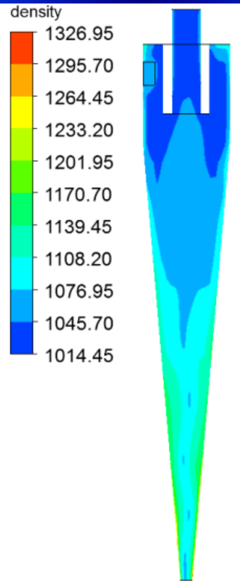
Bhaskar, Mineral Eng (2007)

Euler-Euler Model

$$\frac{\partial}{\partial t}(a_k \rho_k) + \nabla \cdot (a_k \rho_k \vec{v}_k) = 0$$

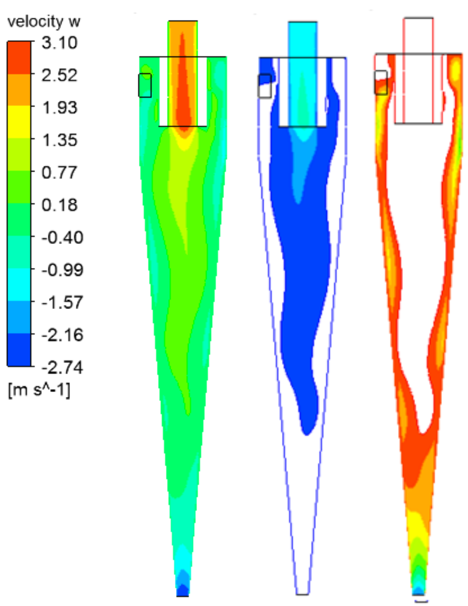
$$\frac{\partial}{\partial t}(a_k \rho_k \vec{v}_k) + \nabla \cdot (a_k \rho_k \vec{v}_k \vec{v}_k) = -a_k \nabla \mathrm{p} + \nabla \cdot \bar{\bar{\tau}}_k + \sum_{p=1}^{n} \vec{R}_{qk} + a_k \rho_k \vec{g} + (\vec{F}_k + \vec{F}_{lift,k} + \vec{F}_{vm,k})$$

III. VALIDATION



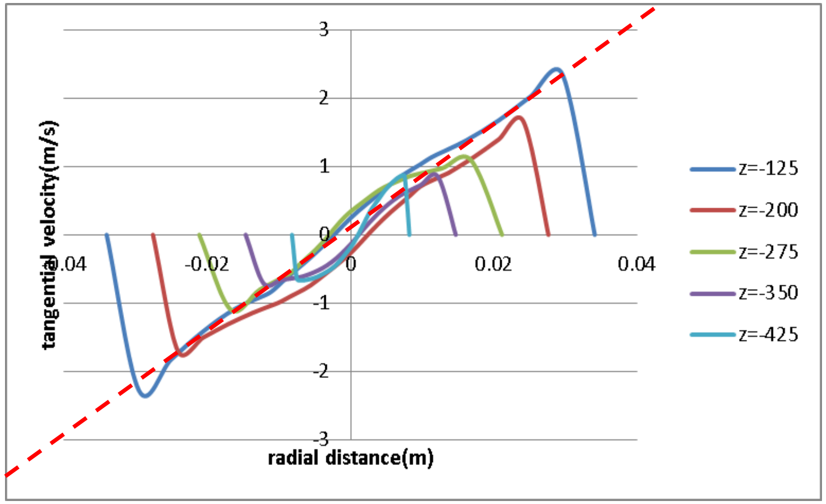
Density

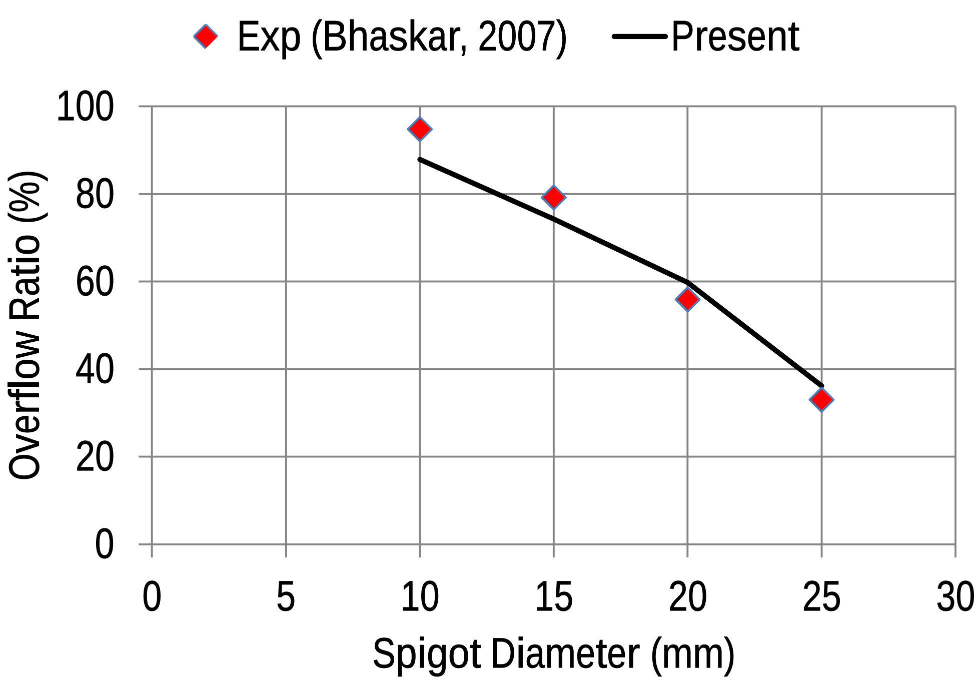
Velocity swirling



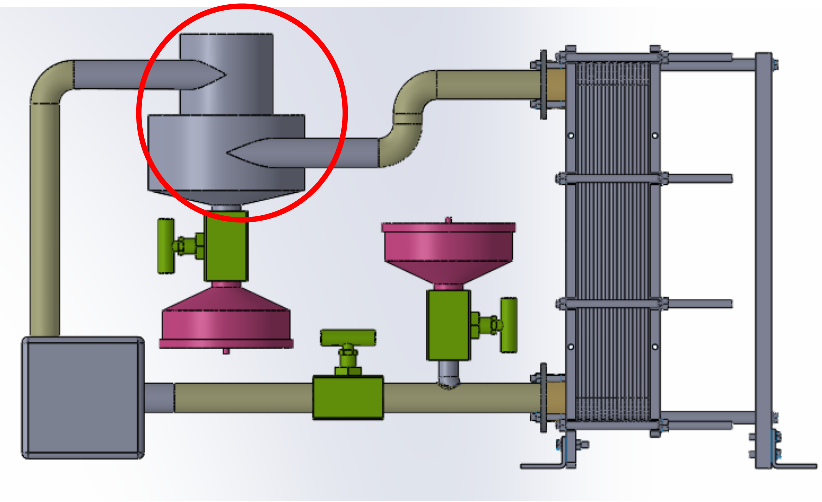
Axial velocity

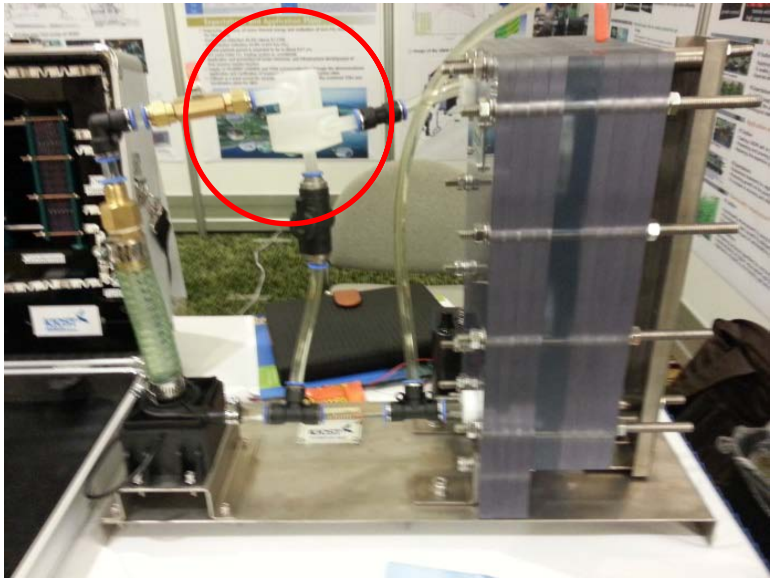
Rotational velocity

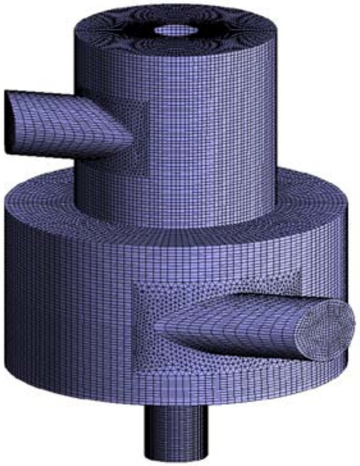


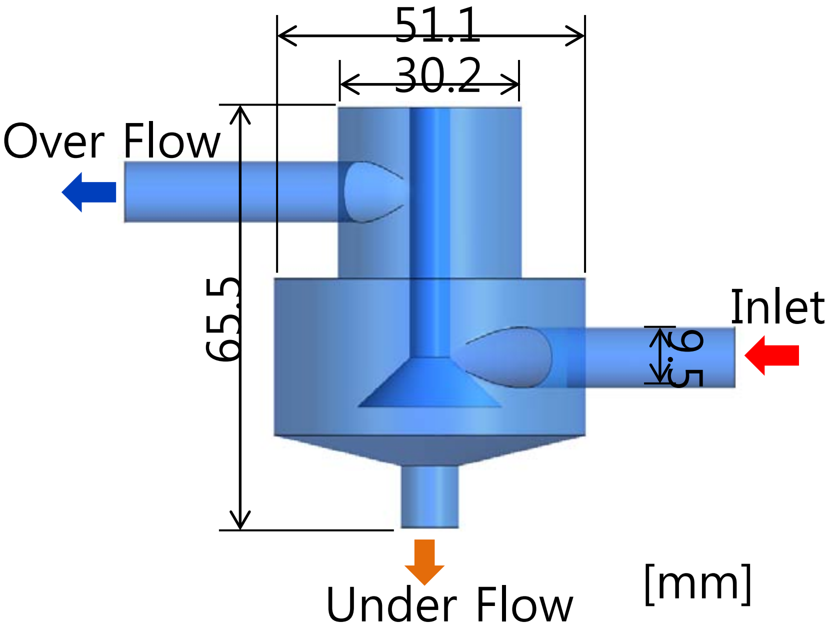


IV. VORTEX SEPARATOR





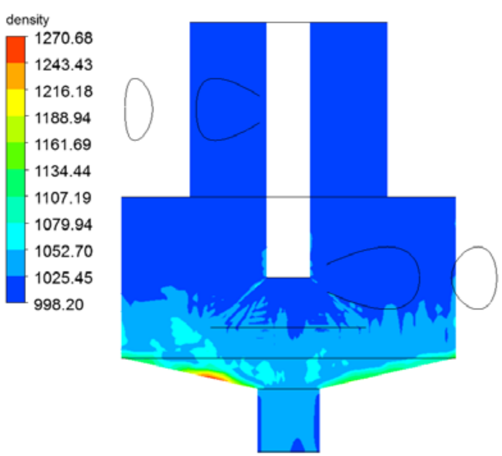




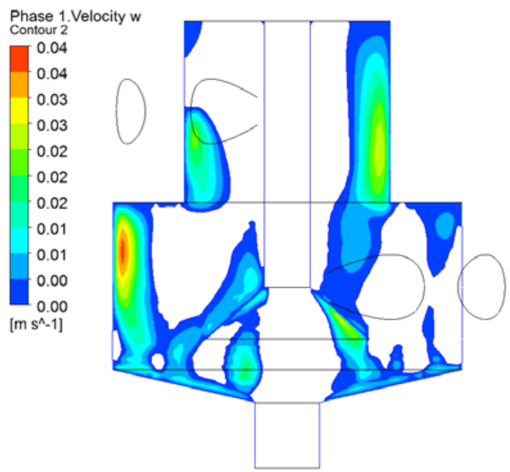
IV. VORTEX SEPARATOR

- **Materials**
  Water Density : 998.2 kg/m3
  Particle Density : 2645kg/m3
  Particle Diameter : 2mm
  Particle Mass Fraction : 22% (Inlet)

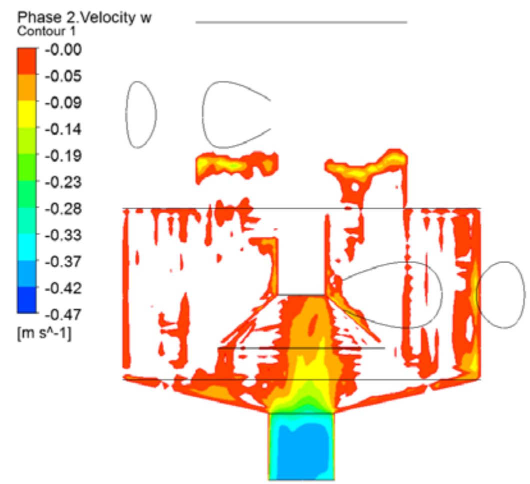
- **Boundary conditions**
  mass flow rate 0.01~0.1kg/s
- **Two-Phase (Liquid-Solid), Granular Flow**
  Re = 1250~12500



Density

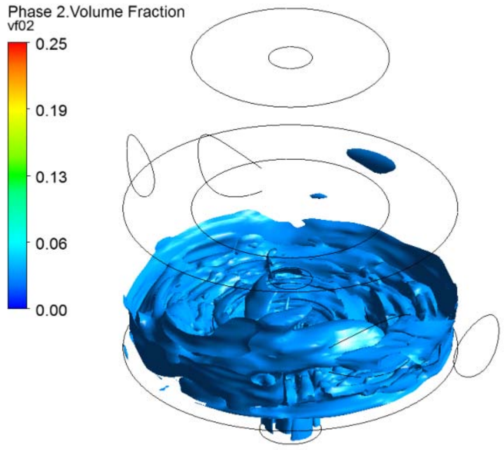


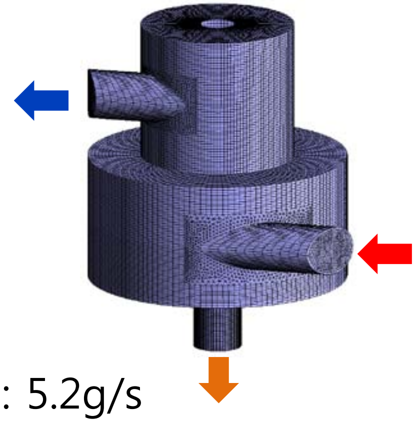
Water axial velocity

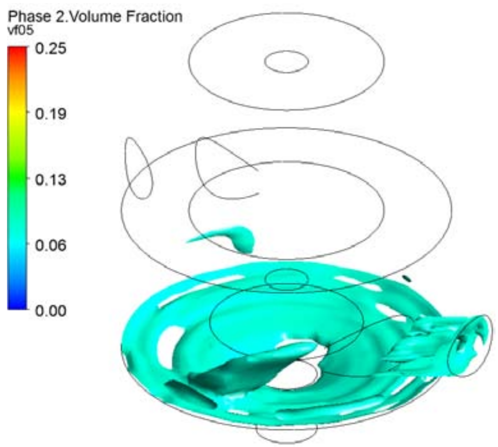


Solid axial velocity

V. COMPUTATIONAL RESULTS







MFR : Mass Flow Rate
SLF : Separated Liquid Fraction
SPF : Separated Particle Fraction

- Complete Filtering is Achieved
- Need to Increase SLF(Over Flow)

Solid iso-volume fraction(3%,8%)

VI. CONCLUDING REMARKS

- Present numerical scheme well simulates flow field inside vortex separator
- Flow inside reflects forced vortex field with linearly decreasing magnitude rotational velocity before it reaches dividing depth.
- When particle diameter reaches up to 2mm, the solid phase is completely separated from liquid phase, showing effective filtering process.
- Will be scaled to prototype based on computational & experimental model

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