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Tianjin University

An SPH Numerical Wave-Current Tank

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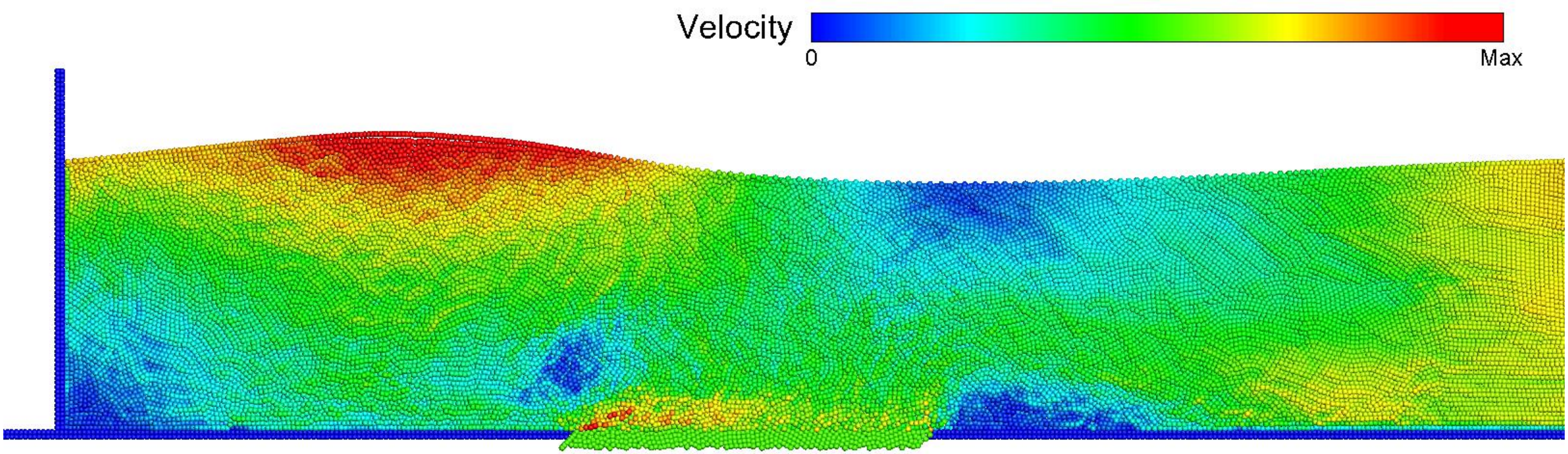
Oct. 20th, 2017

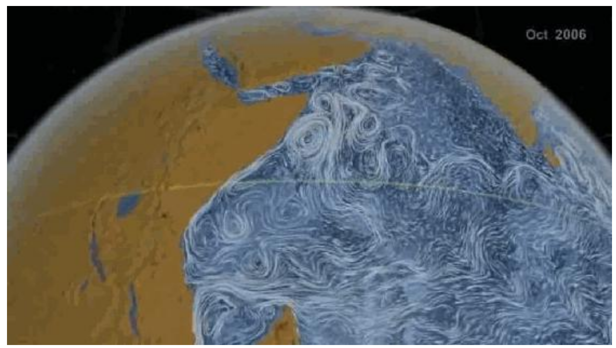


Contents

Background

Ocean dynamic factors

Wave



Current

Tide

Wave & Current

Variable water level

Background

Literature review

1) SPH numerical wave tank (NWT)

Altomare et al. (2017) *Coast Eng*

Wen et al. (2016) *Appl Ocean Res*

Liu et al. (2015) *Coastal Eng*

2) SPH numerical current tank (NCT)

Pahar et al. (2017) *J Hydrol*

Tan et al. (2015) *J Hydro-environ Res*

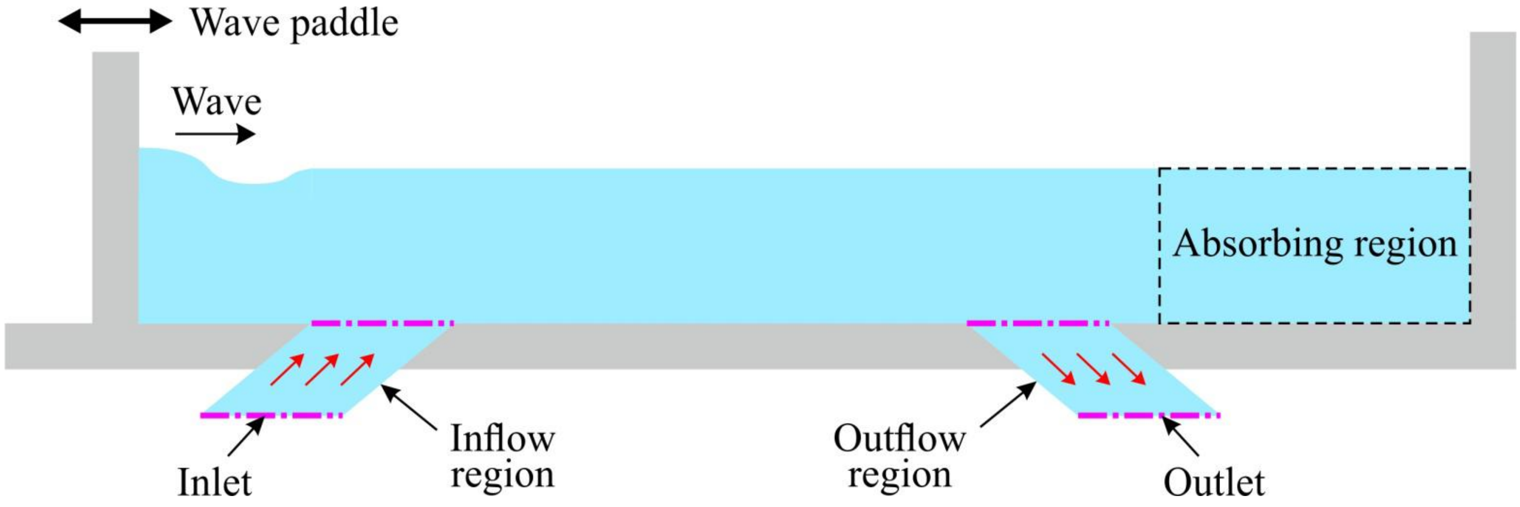
Federico et al. (2012) *Eur J Mech B-Fluid*

3) SPH numerical wave-current tank (NWCT)

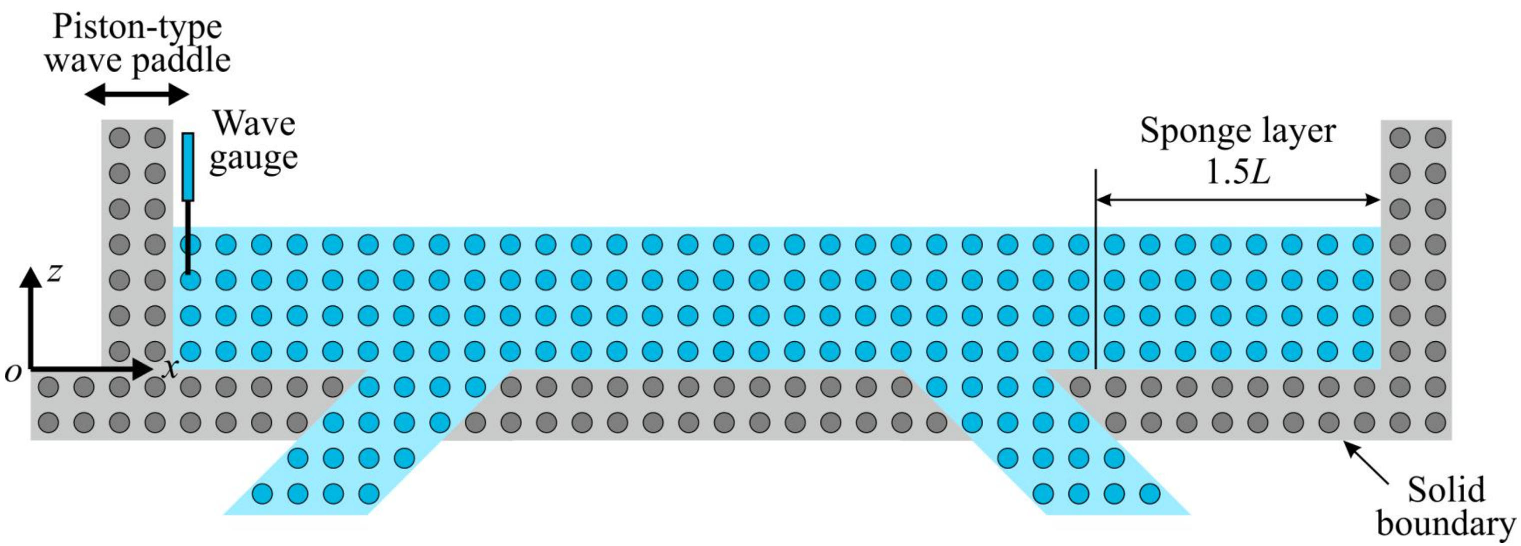
Few

Background

Suggested SPH NWCT



Wave & Current Generations



Wave making

$$V_w = \frac{\partial X_w}{\partial t} = \frac{\omega}{Q}\left[2\eta - \eta_w + DX_w\right]$$

$$Q = \frac{4\sinh^2(kd)}{2kd + \sinh(2kd)} \quad D = \sum_{n=1}^{\infty} \frac{4\sinh^2(k_n d)}{2k_n d + \sinh(2k_n d)}$$

Hirakuchi et al., (1990) *Coast Eng J*

Wave absorbing

$$\frac{\mathrm{d}\boldsymbol{v}_i}{\mathrm{d}t} = -\sum_{j=1}^{N} m_j \left(\frac{p_i}{\rho_i^2} + \frac{p_j}{\rho_j^2} + \Pi_{ij}\right)\nabla_i W_{ij} + \boldsymbol{g} - \mu_s \boldsymbol{v}_i$$

$$\mu_s = \alpha_s \frac{x - x_s}{l_s}; \quad x_s < x < x_s + l_s$$

Wave & Current Generations

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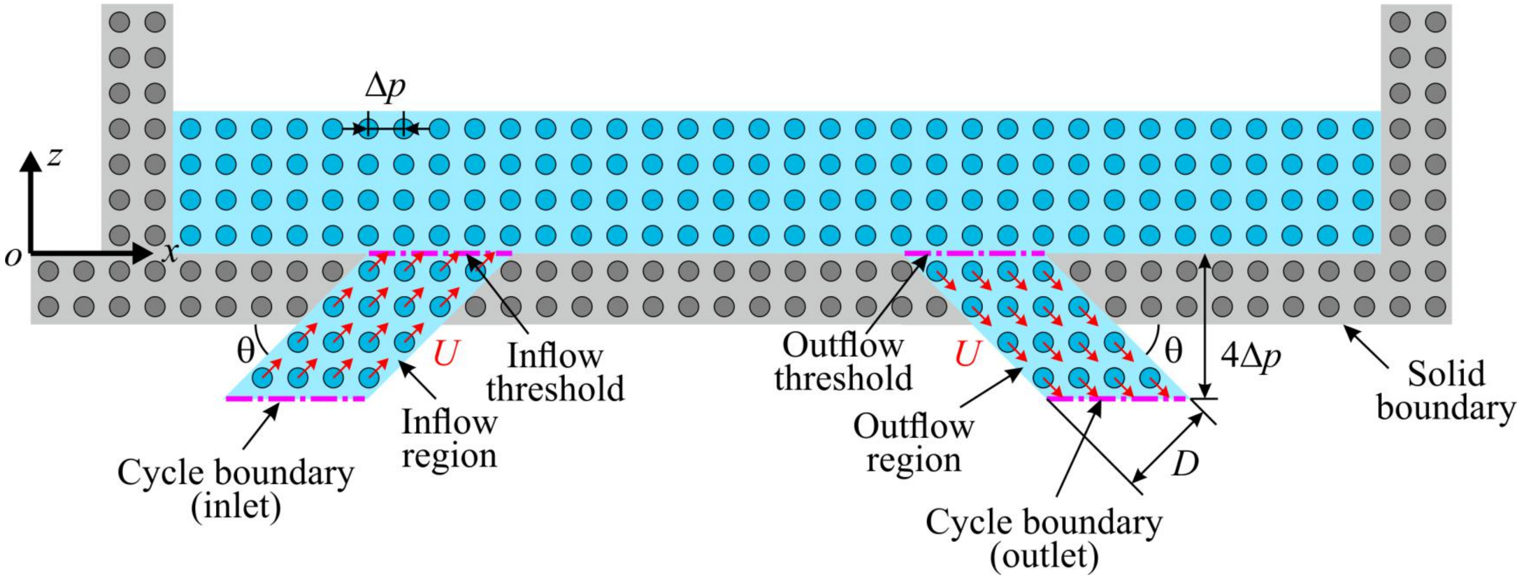


Current generation

Federico et al., (2012) *Eur J Mech B-Fluid*

$$\begin{cases} u_{in} = u_{out} = U\cos\theta \cdot \zeta \\ w_{in} = -w_{out} = U\sin\theta \cdot \zeta \\ p_{in} = p_{out} = \rho_0 g\left(d - z\right) \end{cases}$$

Velocity

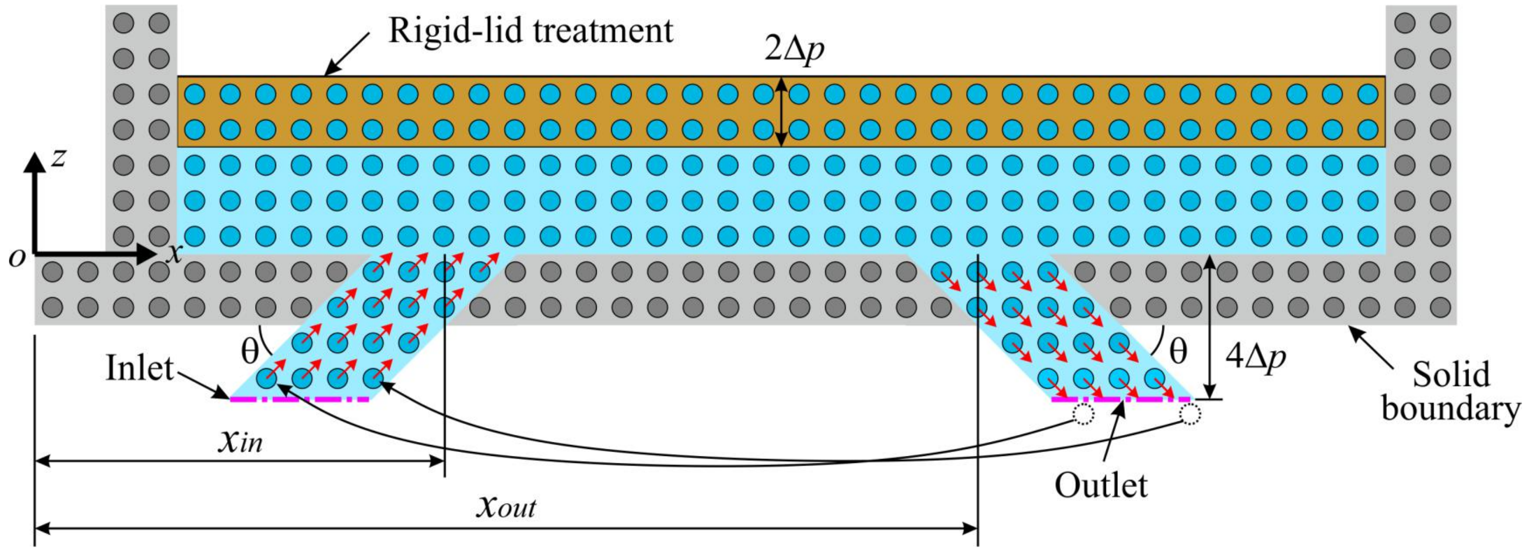
Pressure

Ramp function:

$$\zeta = \begin{cases} 1, & t > t_0 \\ t/t_0, & t \le t_0 \end{cases} \qquad t_0 = \frac{U}{D}\left(\frac{c_0}{g}\right)^2$$

Wave following current: $U > 0$; Wave opposing current: $U < 0$

Wave & Current Generations



Current generation

$$\begin{cases} x' - x = -\left(x_{out} - x_{in} + \dfrac{8\Delta p}{\tan\theta} \right) \\ z' + z = -8\Delta p \end{cases}$$

Wave following current: $x_{out} > x_{in}$

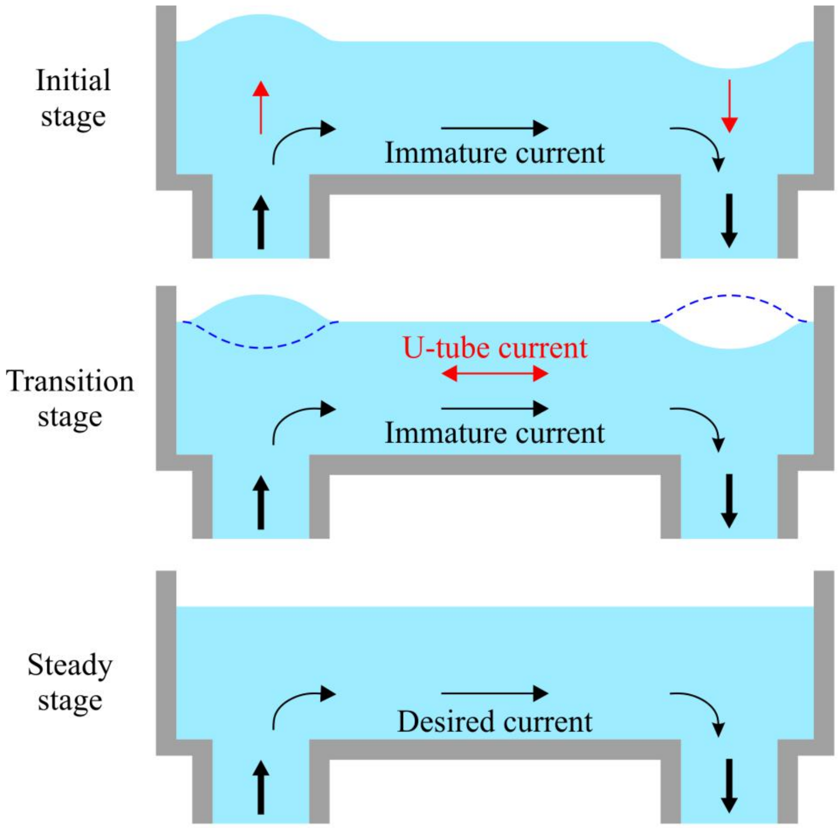
Wave opposing current: $x_{out} < x_{in}$

Rigid-lid treatment:

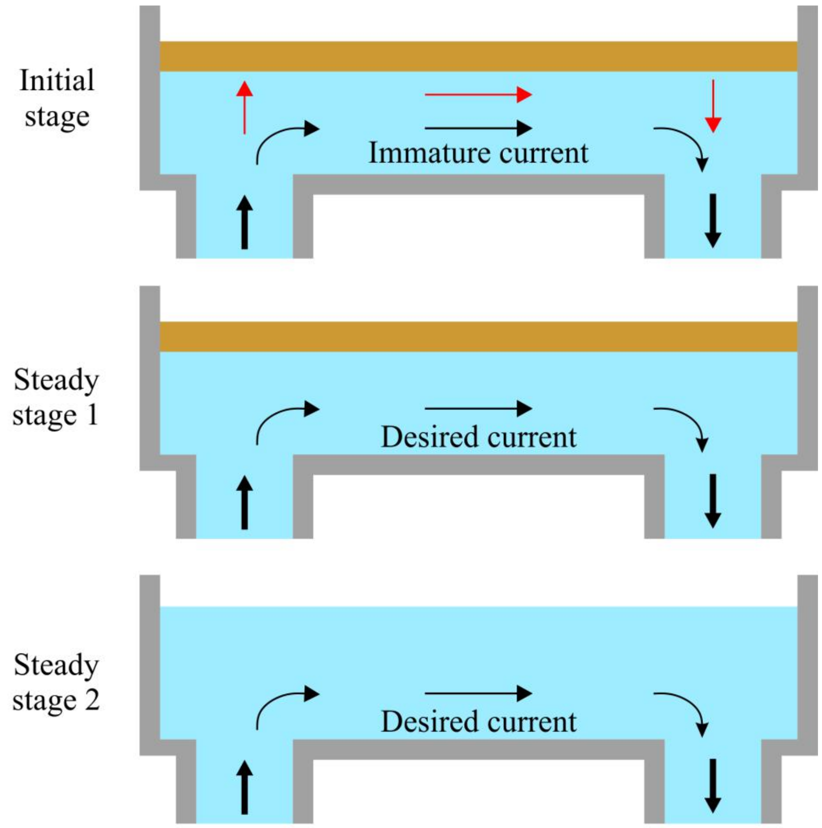
$$w = 0; \quad t \le t_0$$

$$t_0 = \frac{U}{D}\left(\frac{c_0}{g}\right)^2$$

Wave & Current Generations



Without “rigid-lid treatment”



With “rigid-lid treatment”

Validations

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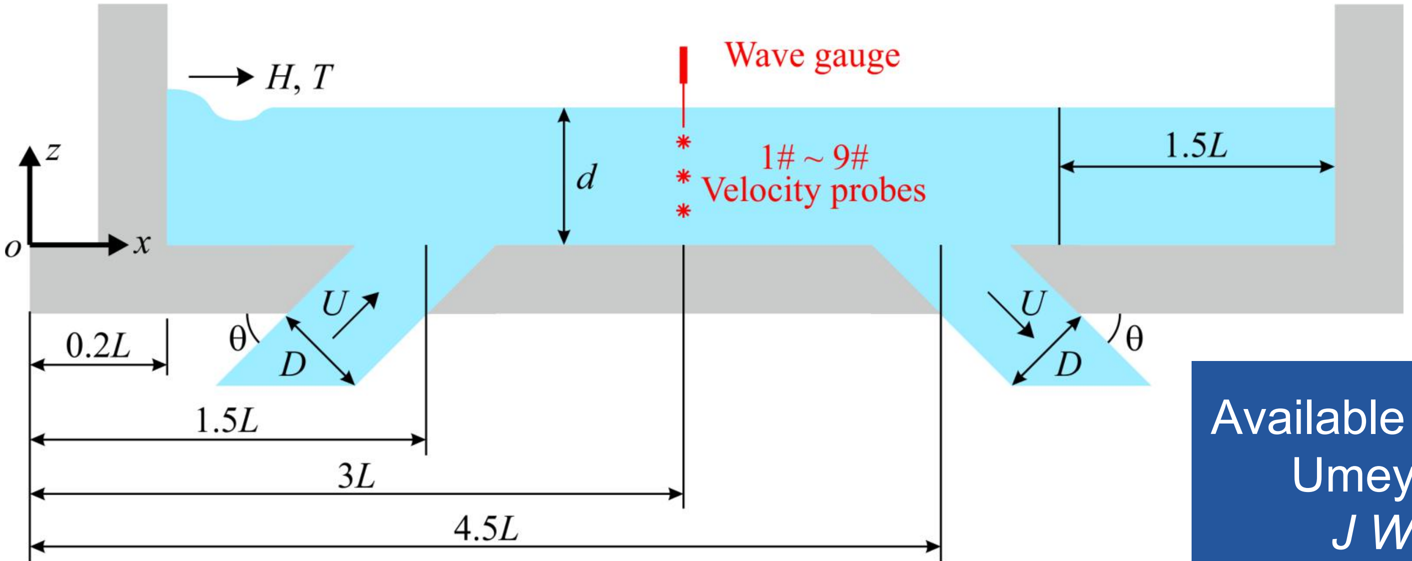


Available Experiment:
Umeyama (2011)
J Waterw Port Coast

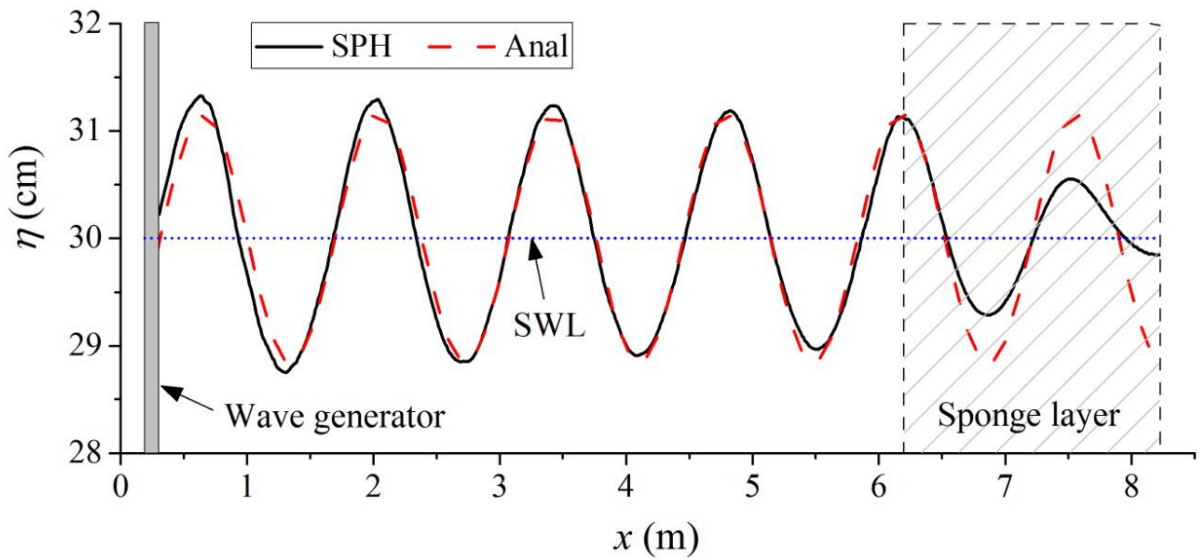
Measurement points	
Wave gauge	$x = 3L$
Velocity probes	$x = 3L$ $z_1 = 3$ cm $z_2 = 6$ cm … $z_9 = 27$ cm

Wave parameters	
H	2.34 cm
T	1.0 s
d	0.30 m
L	1.373 m

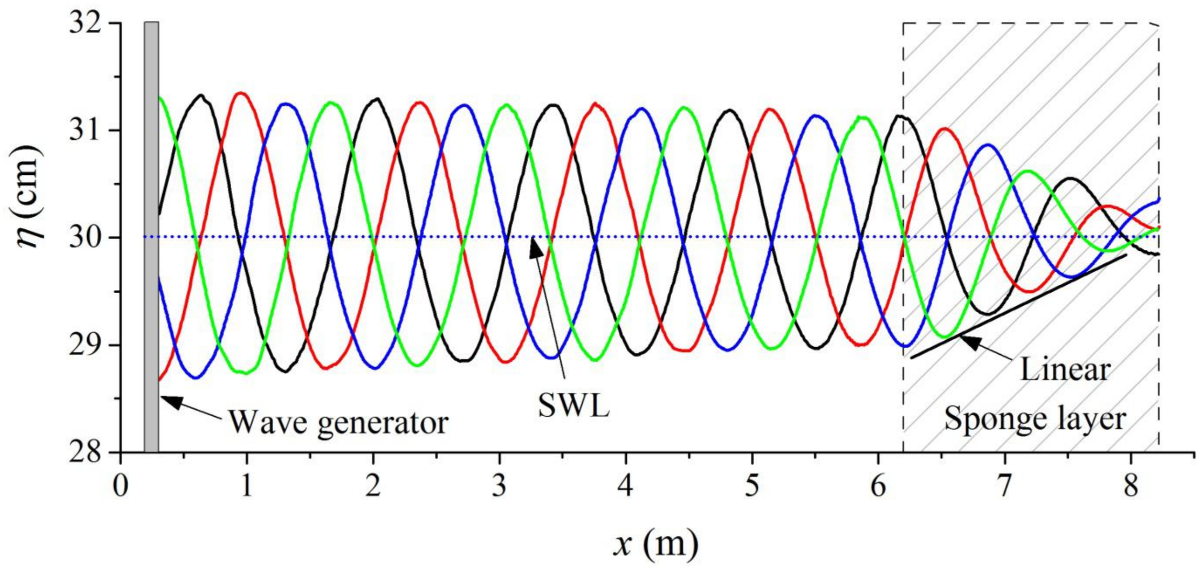
Current parameters	
U	8 cm/s
D	0.3 m
θ	45 deg

Validations (Wave-alone)

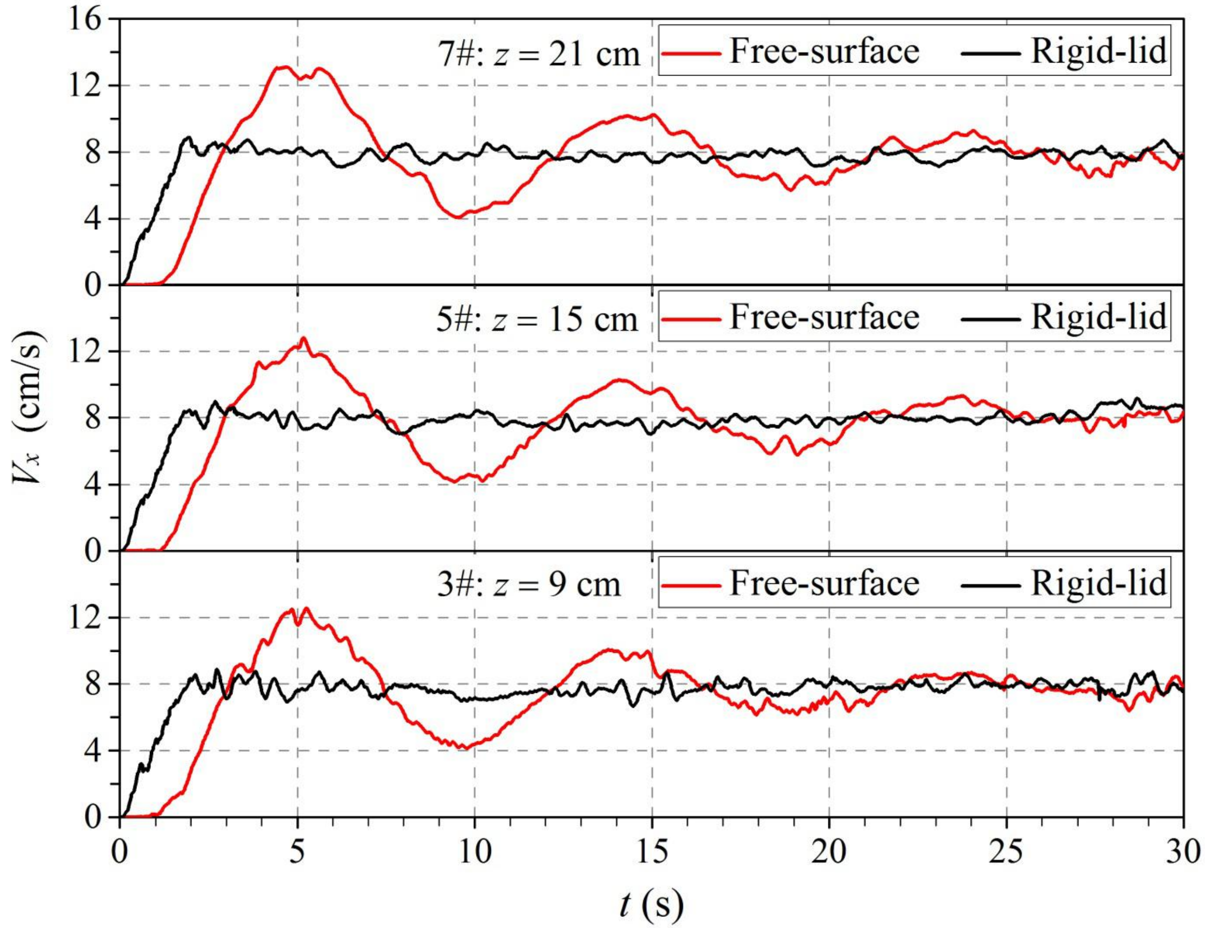
Snap shot



Multi-frame observation

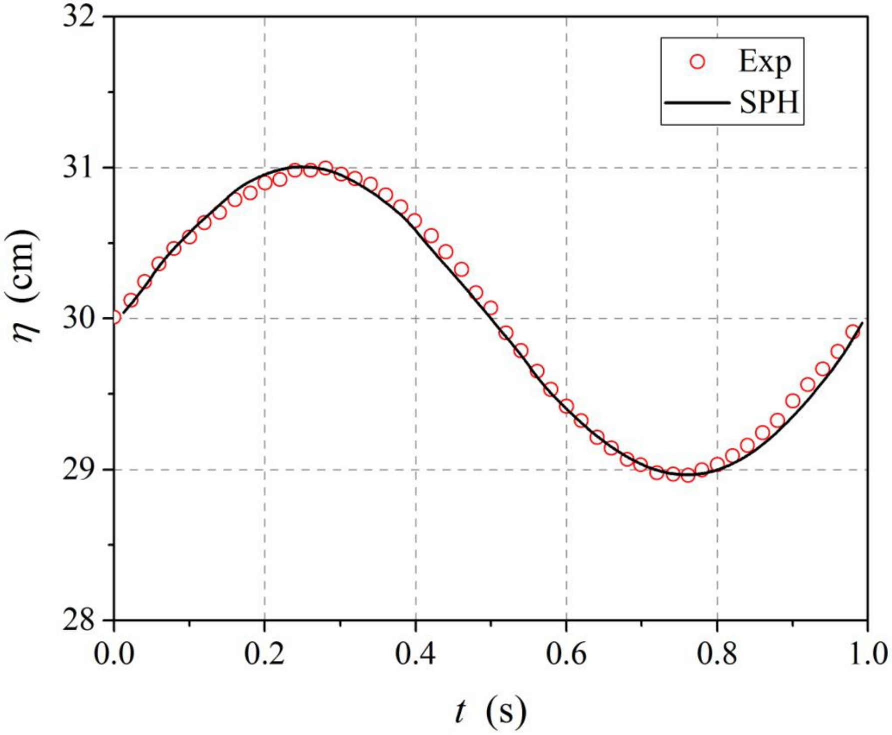


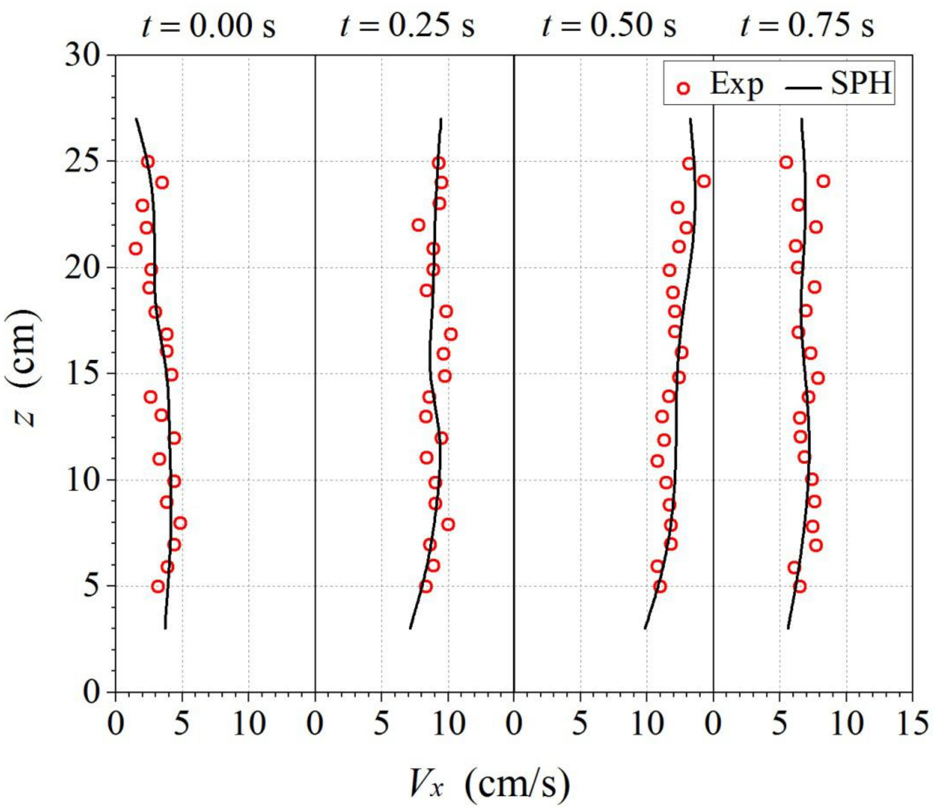
Validations (Current-alone)



Velocity comparison (Target V_x = 8 cm/s)

Validations (Wave following current)





Wave profile comparison

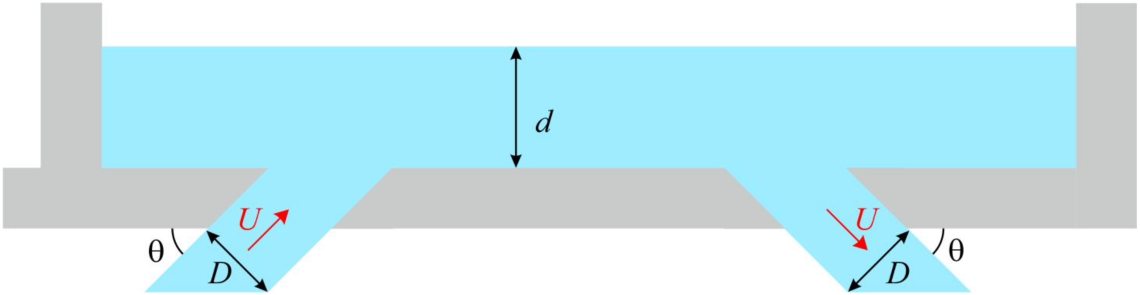
Velocity distribution comparison

Future Work

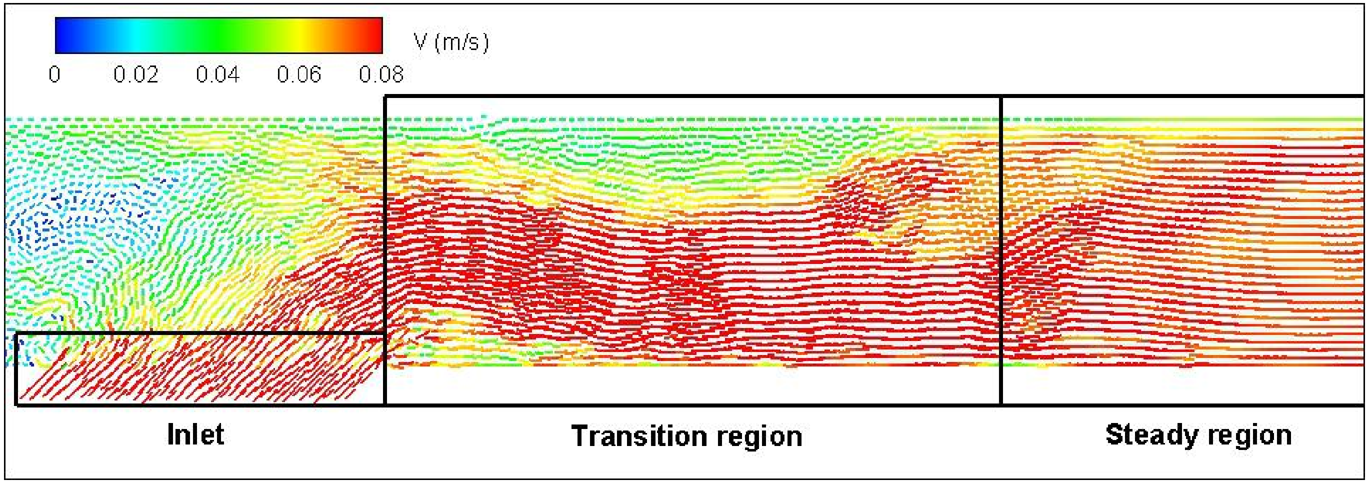
1) Validation on wave opposing current

2) Convergence check

3) Optimizations of θ and D



4) Finding the effective region



Thanks for listening!

We appreciate any comments and suggestions!

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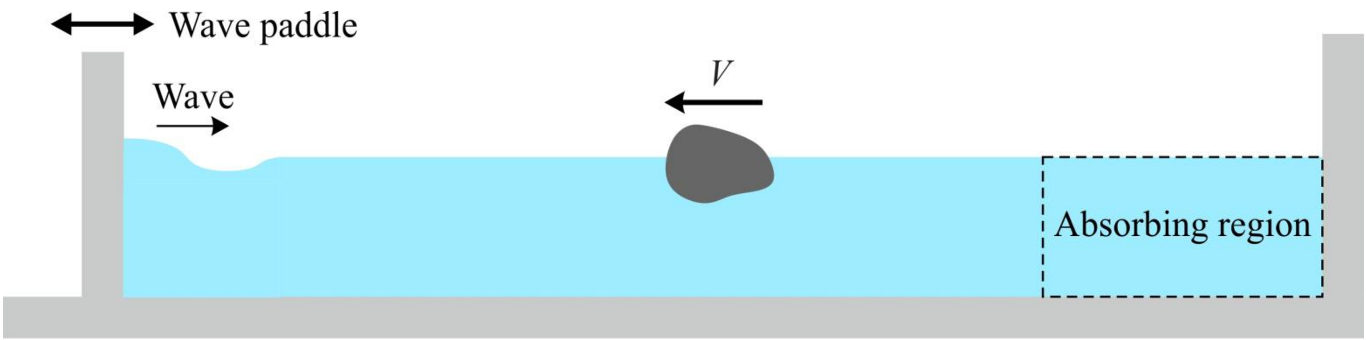
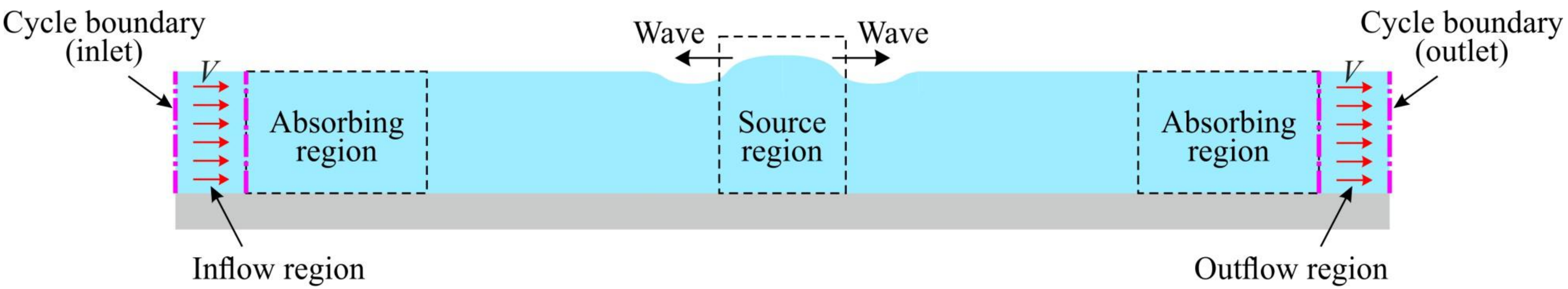
Potential SPH NWCTs

1) Wave paddle + Trailing structure



2) Internal wavemaker + Lateral velocity inlet/outlet



SPH Model

Governing equations (Wendland kernel)

$$
\begin{cases}
\dfrac{d\rho_i}{dt} = \sum_j m_j \boldsymbol{u}_{ij} \cdot \nabla_i W_{ij} \\
\dfrac{d\boldsymbol{u}_i}{dt} = -\sum_j m_j \left(\dfrac{p_i}{\rho_i^2} + \dfrac{p_j}{\rho_j^2} + \Pi_{ij} \right) \nabla_i W_{ij} + \boldsymbol{g} \\
p = B\left[\left(\dfrac{\rho}{\rho_0} \right)^{\gamma} - 1 \right] \\
\dfrac{d\boldsymbol{r}_i}{dt} = \boldsymbol{u}_i - \varepsilon \sum_j \dfrac{m_j \boldsymbol{u}_{ij}}{\bar{\rho}_{ij}} W_{ij}
\end{cases}
$$

Density filter (Every 30 time steps)

$$
\rho_i = \sum_j m_j \frac{W_{ij}}{\sum_j \frac{m_j}{\rho_j} W_{ij}}
$$

Solid boundary treatment

Dynamic Boundary Condition (DBC)

(Dalrymple and Knio, 2001)

(Ren et al., 2015) *APOR*