バネ・ダッシュポット支持された捕捉粒子で分離される粒子群と自由表面流れの計算

Computation of Moving Particles and Free-Surface Flows around Trapping Particles Fixed with Spring and Dashpot Model

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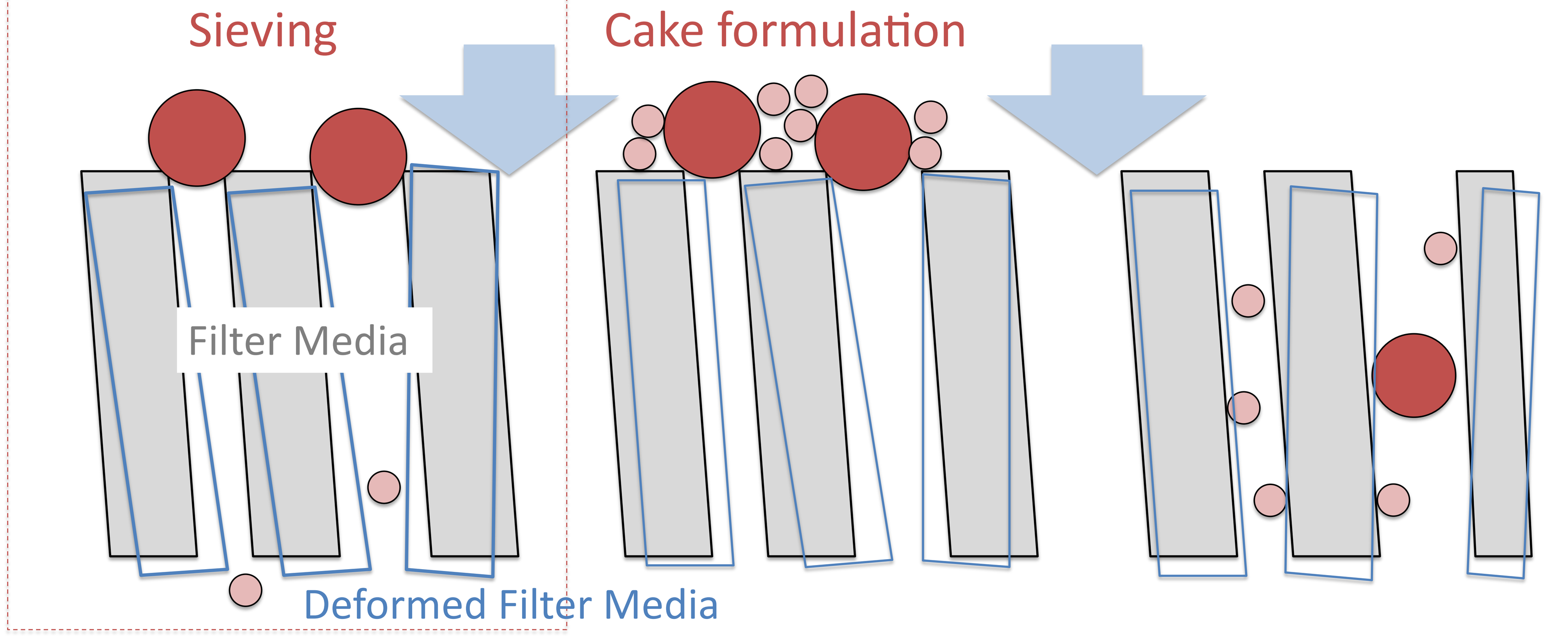
Research Background and Filtration Mechanics

Filtration	Life	Industry
Liquid	Drinking water Washing machine Aquarium …	Semiconductor plant Inkjet printer Water treatment …
Gas	Air conditioner Vacuum cleaner Mask …	Clean room Air conditioning facility Dust collector …

(Source,http://www.taki-eng.co.jp/filter.html)

Liquid and gas filtration technology is playing a important role in our society.



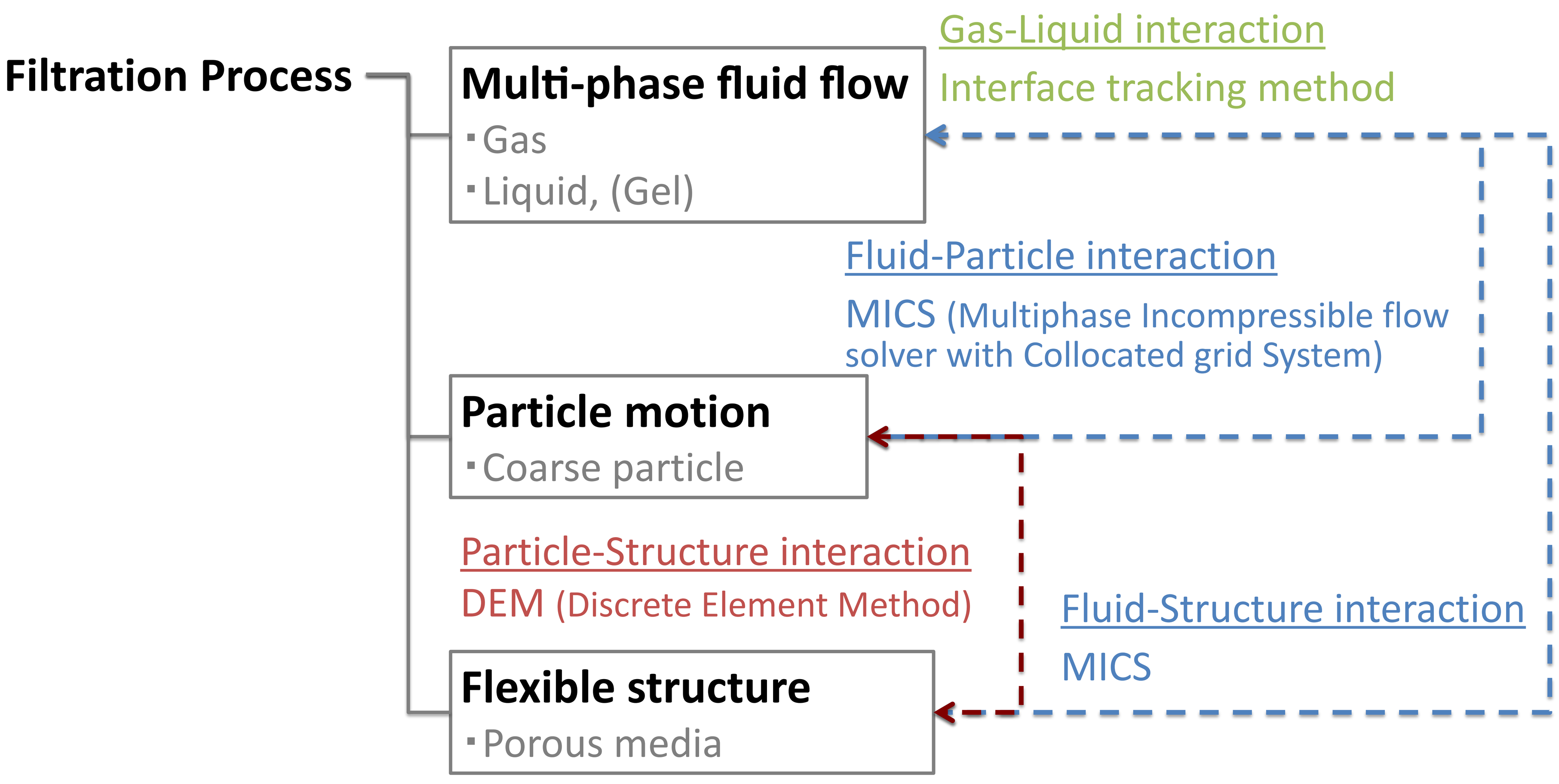
Nonwoven filter media is deformed under pressure fluctuation

Surface filtration: Particles are retained on surface of medium

Depth filtration: Particles are retained though depth

Unnecessary substances are captured by nonwoven porous media based on these mechanics.

Framework of the Filtration Process Simulation



Flexible structure is modeled with a spring and dashpot

Momentum equation
$$\frac{\partial u_i}{\partial t}+\frac{\partial}{\partial x_j}(u_i u_j)=g_i-\frac{1}{\rho}\frac{\partial p}{\partial x_i}+\frac{1}{\rho}\frac{\partial}{\partial x_j}\left[\mu\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)\right]$$

Incompressible condition
$$\frac{\partial u_j}{\partial x_j}=0$$

u_i, x_i, g_i : velocity, coordinate, gravity acceleration
t, ρ, μ, p : time, density, viscosity, pressure

Interface tracking method on Euler mesh
$$\frac{\partial \phi}{\partial t}+\frac{\partial(\phi u_j)}{\partial x_j}=0$$

ϕ : scalar variable (0: gas, 1: liquid)
$\alpha_k, \Delta V, \sigma_k$: particle ratio in a cell, volume of a cell, density of particle

Fluid force on solid
$$f_i=\alpha_k \Delta V \sigma_k\left[-\frac{1}{\rho}\frac{\partial p}{\partial x_i}+\frac{1}{\rho}\frac{\partial}{\partial x_j}\left\{\mu\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)\right\}\right]$$

Equation of translational and rotational motion of a "moving particle"
$$m^p\frac{\partial v_i^p}{\partial t}=f_i^p+s_i^p+g_i^p$$
$$I^p\frac{\partial w^p}{\partial t}=m_c^p$$

f_i: fluid force, s_i: contact force,
g_i: gravitational force
I: moment of inertia, w: angular velocity
m_c: moment on a particle

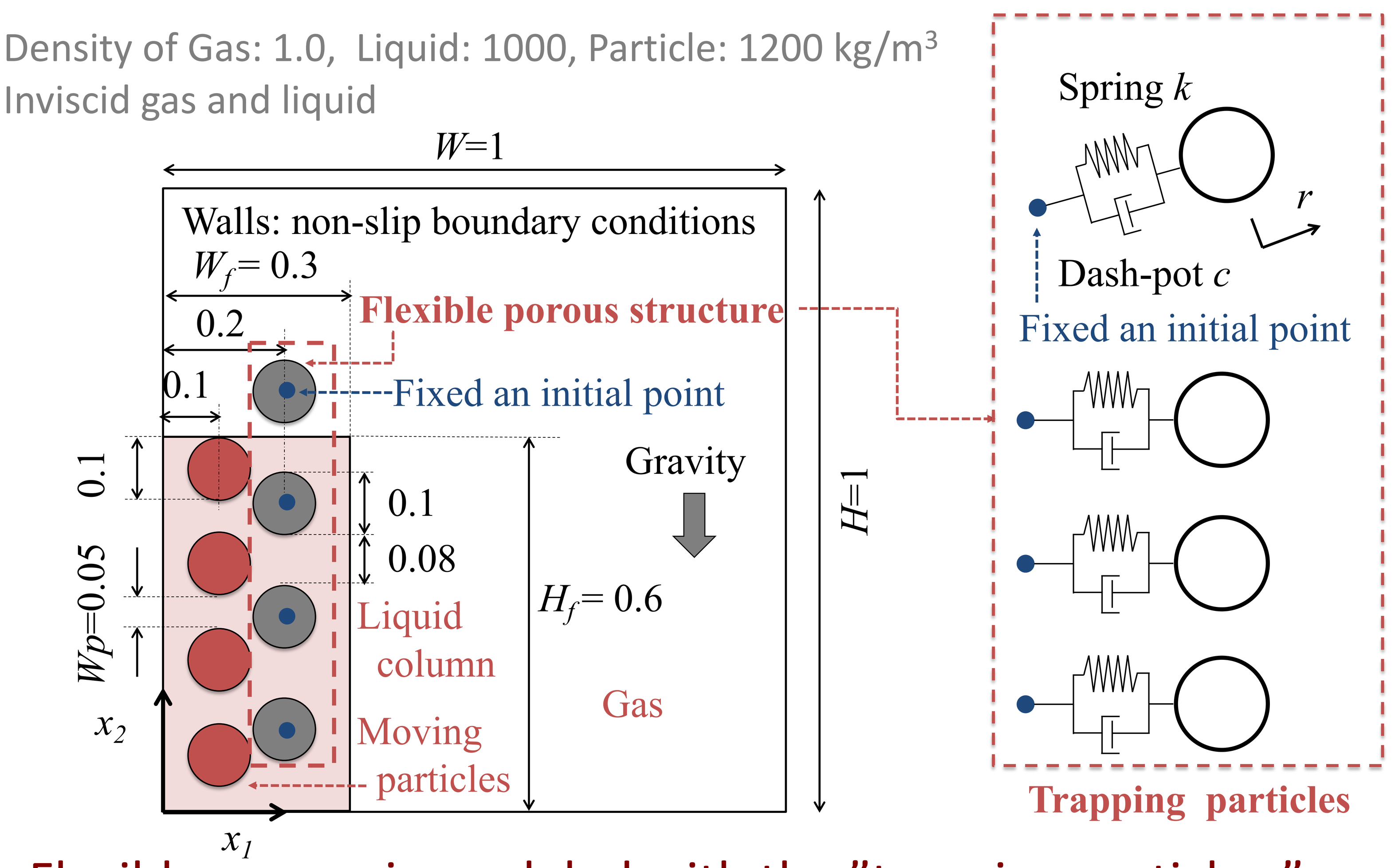
Equation of translational and rotational motion of a "trapping particle"
$$m^s\frac{\partial v_i^s}{\partial t}=f_i^s+s_i^s+g_i^s+h_i^s$$
$$I^s\frac{\partial w^s}{\partial t}=m_c^s$$
$$h^s=-c\frac{dr}{dt}-k(r-r_0)$$

h: viscoelastic force
r : position of a trapping particle
r_0: initial position of a trapping particle
c: damping coefficient
k: spring constant

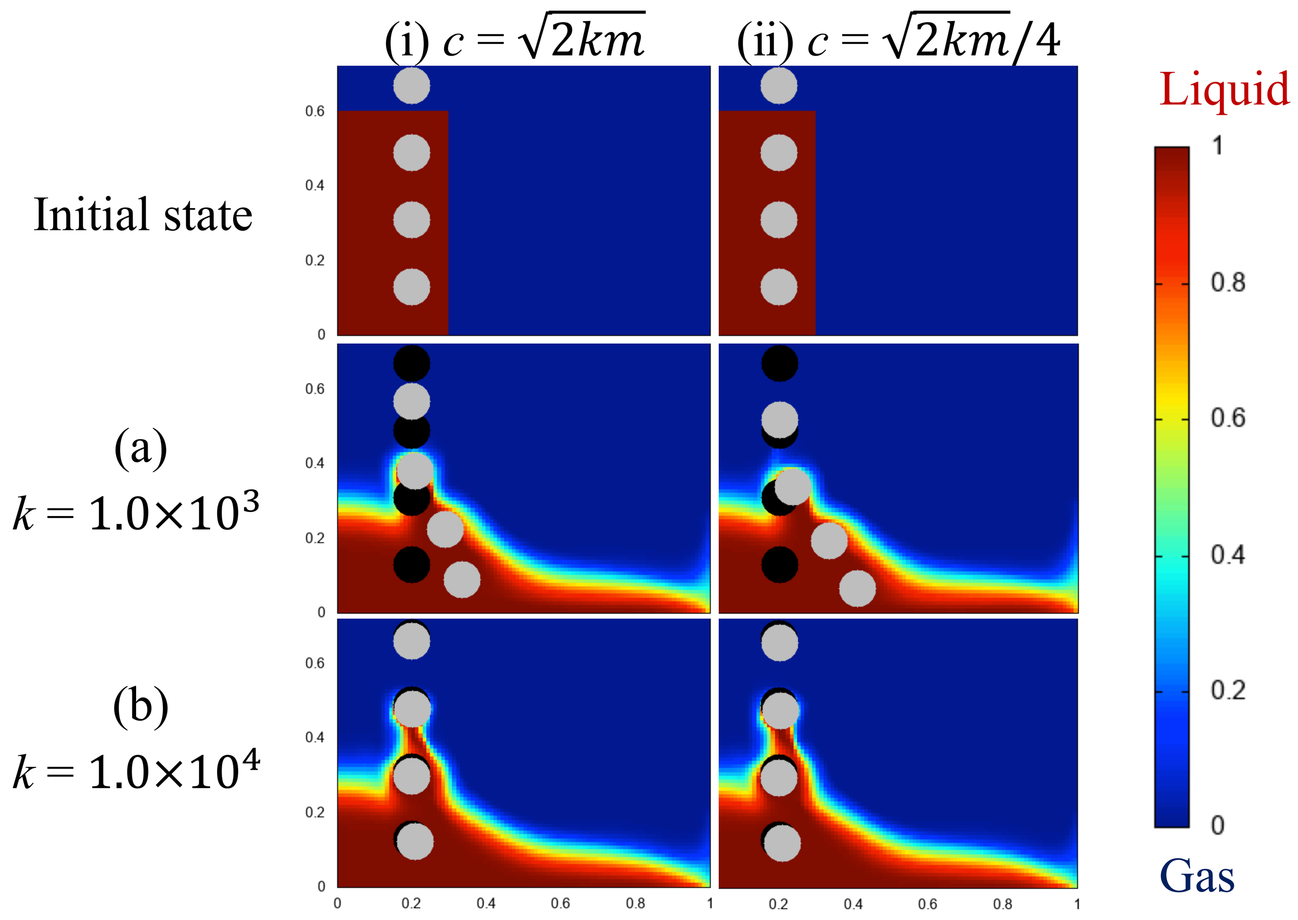
Multi-physical processes are calculated by MICS, DEM and Interface tracking method.

Flexible Porous Structure Model and Sieving Filtration

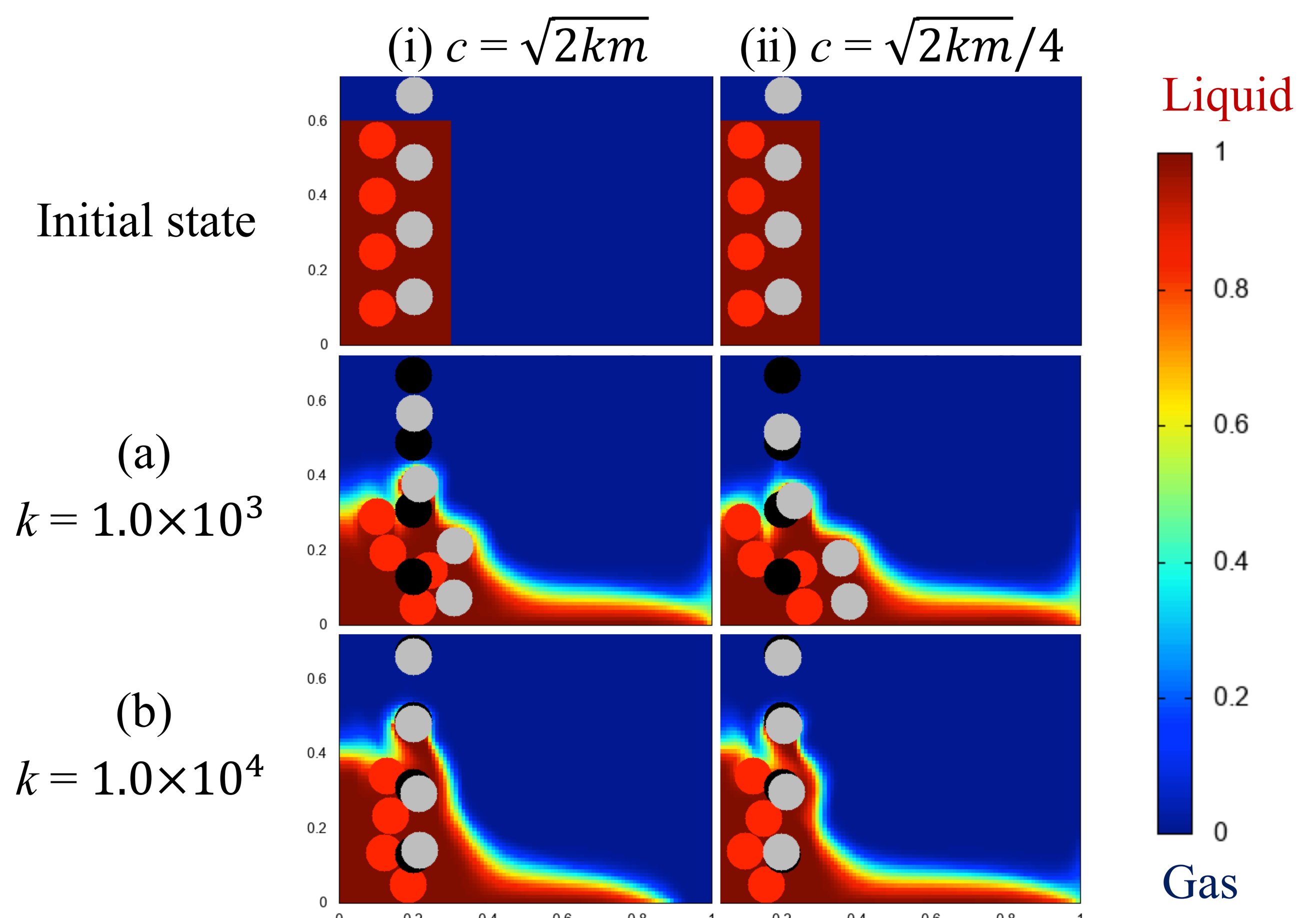
Density of Gas: 1.0, Liquid: 1000, Particle: 1200 kg/m^3
Inviscid gas and liquid



Flexible porous is modeled with the "trapping particles", connecting to its initial position with a spring and dash-pot.



The porous structure is demonstrated to be flexible and deformed depending on the spring k and dashpot c .



Sieving filtration is demonstrated numerically, retaining the "moving particles" by the "trapping particles".

- The applicability of the two-dimensional computational method was discussed to predict the sieving filtration, which is used to trap "moving particles" from the particle-laden liquid flows.
- A flexible porous structure for the sieving filtration is modeled with the "trapping particles", each of which connects to its initial position with a spring and dash-pot structure.
- The dam-break liquid flows including moving particles were calculated in the area where the trapping particles were placed. As a result, it was shown that the moving particles are retained by the trapping particles and that the sieving filtration is reasonably simulated.