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Application of particle-based computational acoustics to sound propagation and scattering

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Contents

Motivation

The acoustic properties of ship wake are the basic factors to track and identify.

Motivation

Particle Method (Meshfree & Lagrangian approach)

a. no numerical error in computing advection term;

b. complex domain geometry;

c. moving boundaries a

d. local support domain

Acoustic Problems

a. bubble Acoustics

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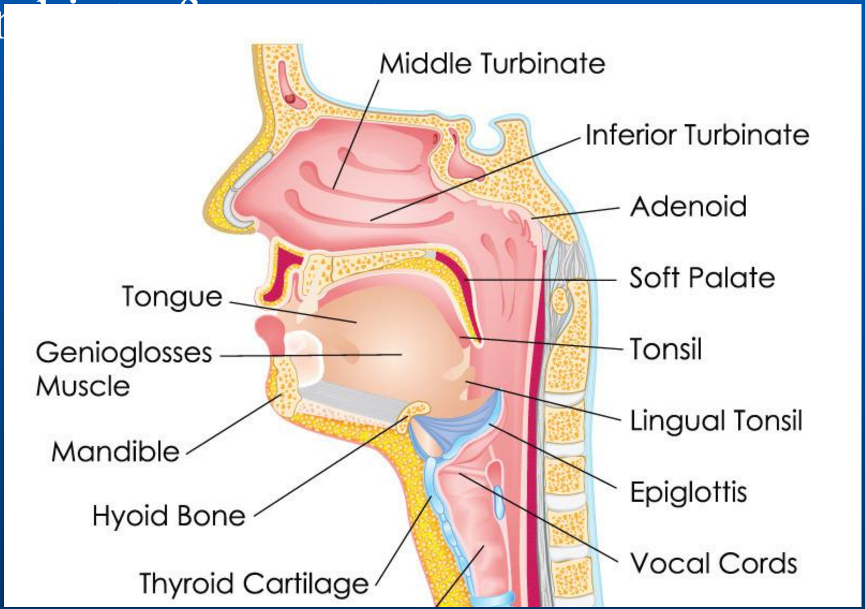
Acoustic Problems

a. bubble acoustics

b. human voice



Motivation

Particle Method (Meshfree & Lagrangian approach)

a. no numerical error in computing advection term;

b. complex domain geometry;

c. moving boundaries and interface

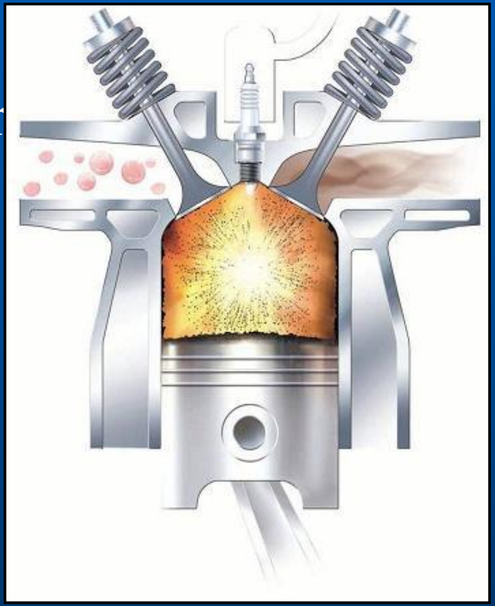
d. local support domain suitable for

Acoustic Problems

a. bubble acoustics

b. human voice

c. combustion noise



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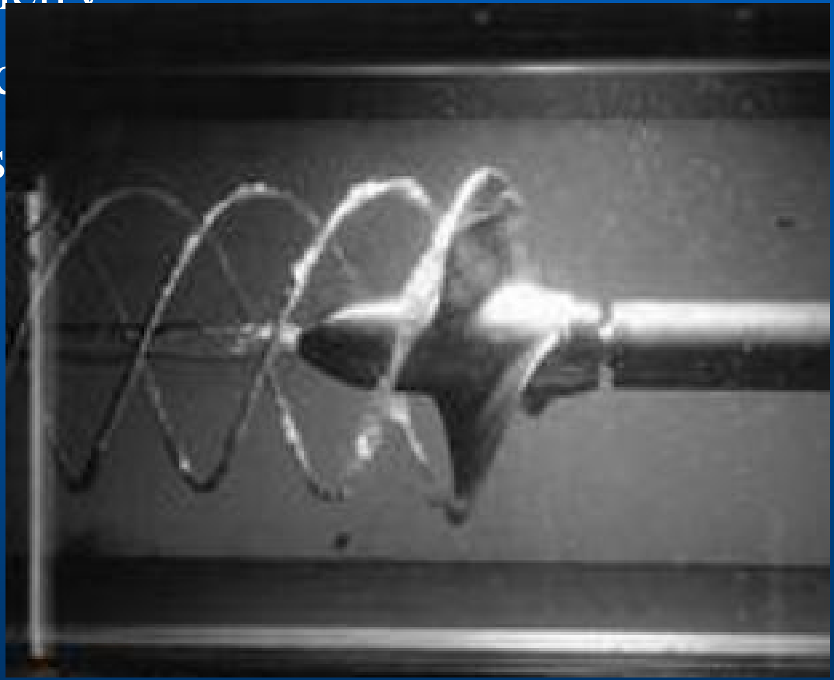


Motivation

Particle Method (Meshfree & Lagrangian approach)

a. no numerical error in computing advection term;

b. complex domain geometry;

c. moving boundaries and interface capture;

d. local support domain suitable for parallel computing.

Acoustic Problems

a. bubble acoustics

b. human voice

c. combustion noise

d. cavitation noise

Particle-based

Computational Acoustics

(PCA)

Contents

Governing Equations

What do we need from SPH computation?

I. Direct numerical simulation

· include full flow-sound interaction

II. Acoustic perturbation model (hybrid method :CFD + CA)

· separate sound from background flow (LEE)

· partial coupling

III. Equivalent sound source model

· use sound source to replace the target

Contents

Numerical Method

I. Smoothed particle hydrodynamics (SPH)

· widely used fundamental particle method

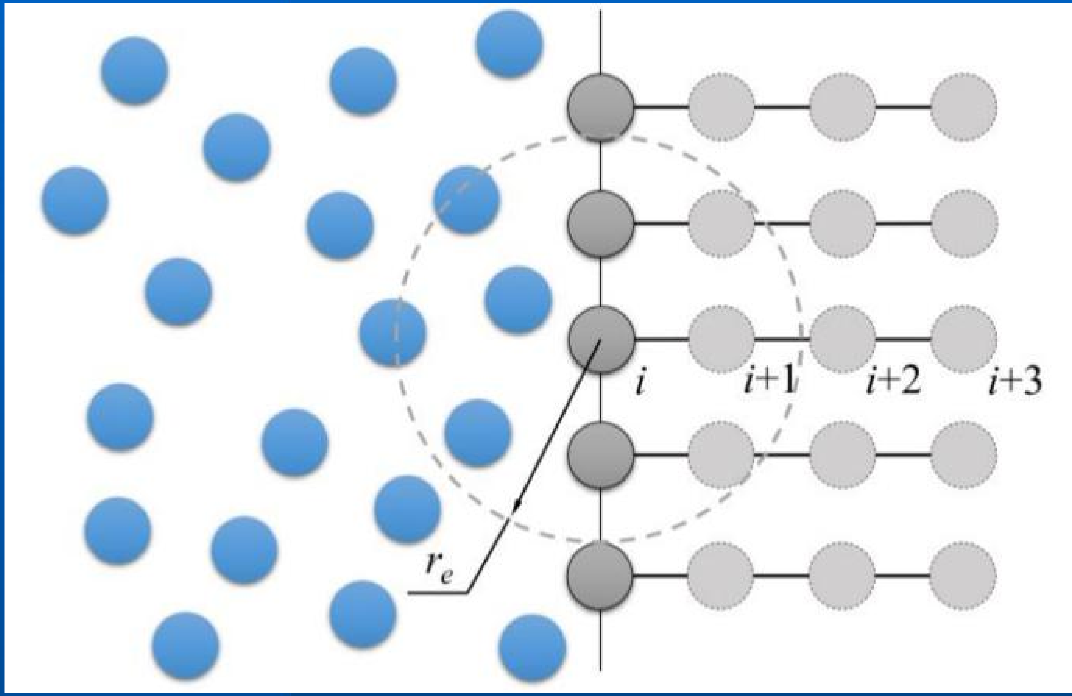
II. Corrective smoothed particle method (CSPM)

· modify SPH with Taylor series expansion

III. Symmetrical smoothed particle hydrodynamics (SSPH) / Finite difference particle method (FDPM)

· developed from generalized finite difference scheme

Numerical Method (acoustic boundary)



Acoustic boundary conditions can be represented with different finite difference scheme to obtain high order accuracy.

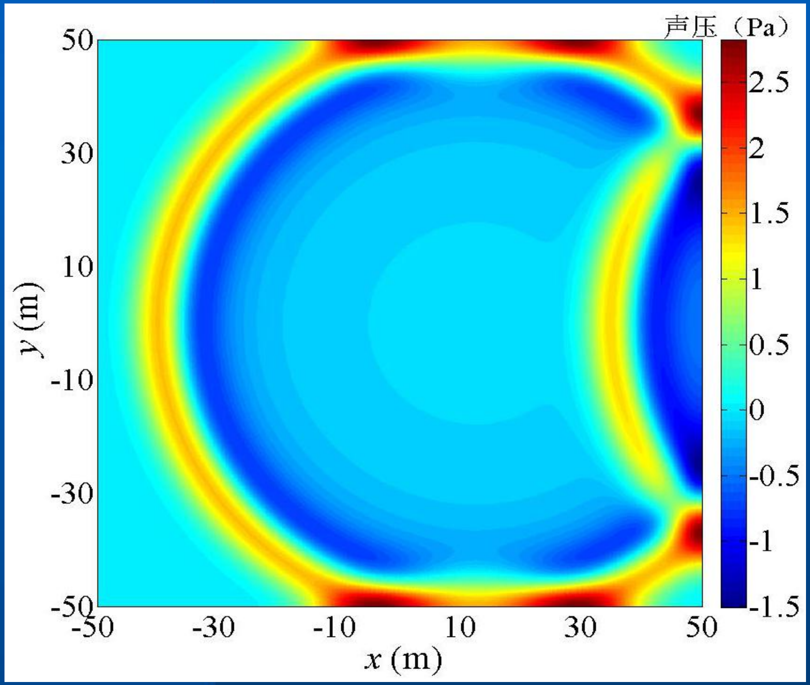
Absorbing boundary:

$$f^n(i+3,j) = f^{n-1}(i,j) + \frac{c_0\Delta t - u_0\Delta t - 3\Delta x}{c_0\Delta t - u_0\Delta t + 3\Delta x}\left[f^n(i,j) - f^{n-1}(i+3,j)\right]$$

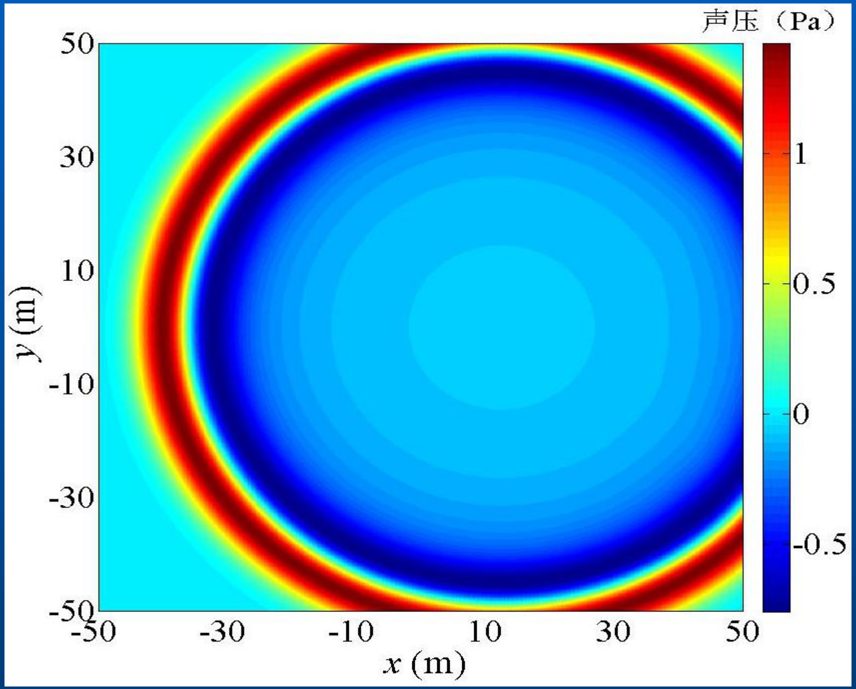
Contents

Tests and Discussion

Test 1 acoustic boundary (acoustic wave equation)



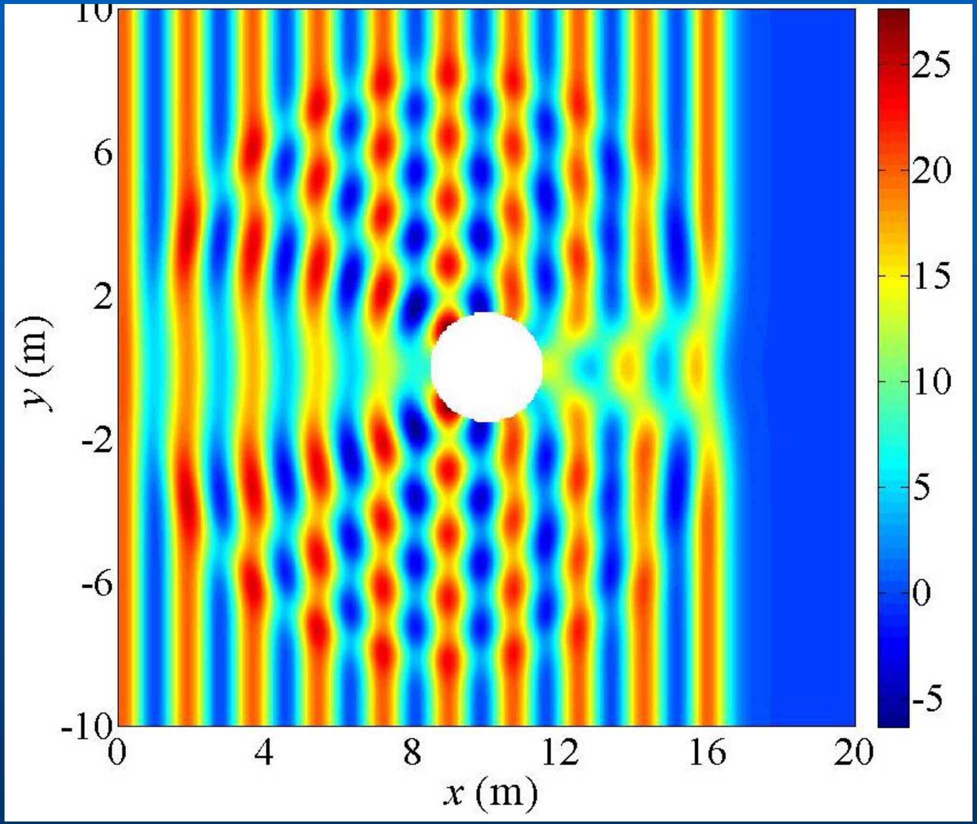
Rigid boundary



Absorbing boundary

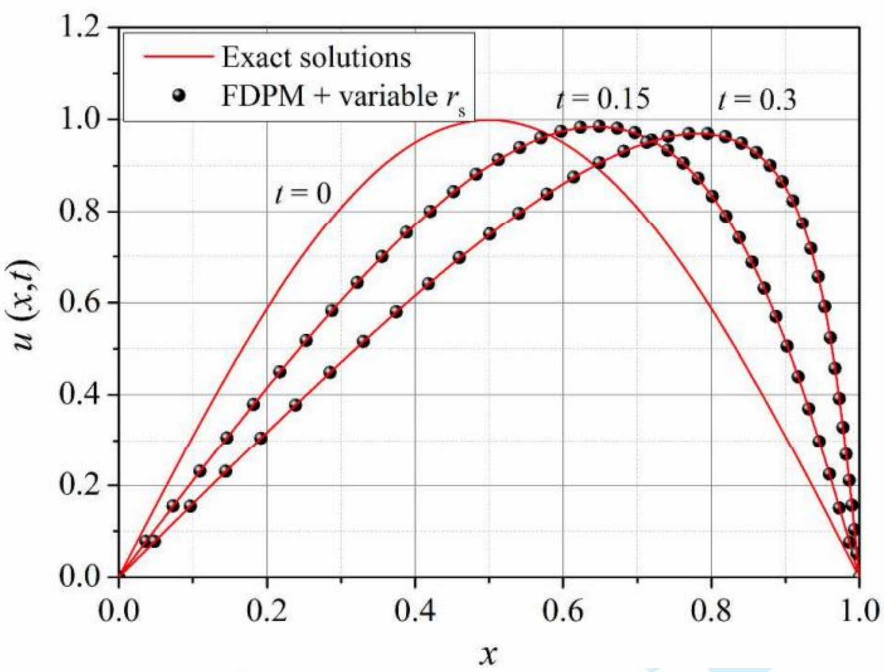
Tests and Discussion

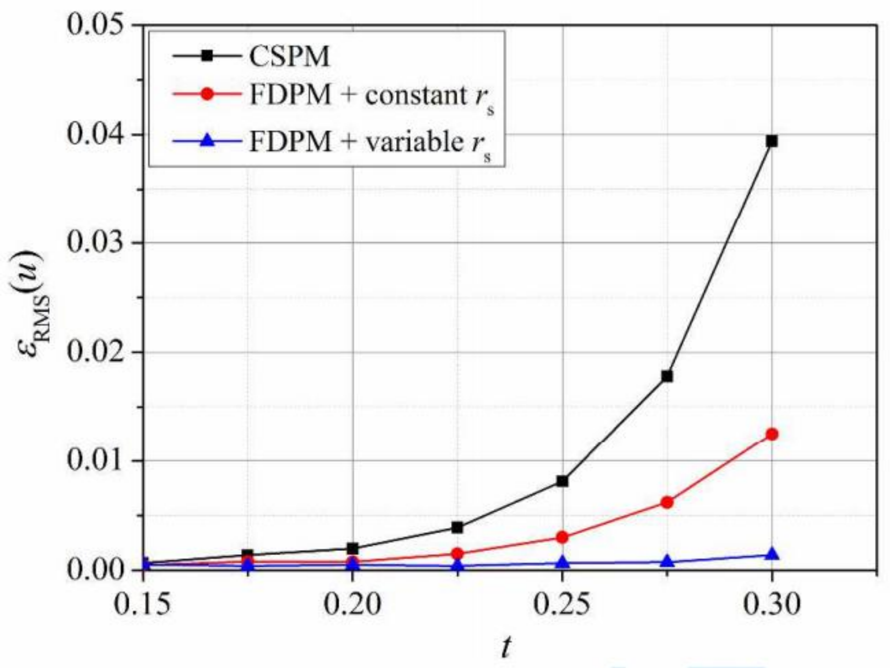
Test 1 acoustic boundary (scattering)



Tests and Discussion

Test 2 nonlinear acoustic wave equation

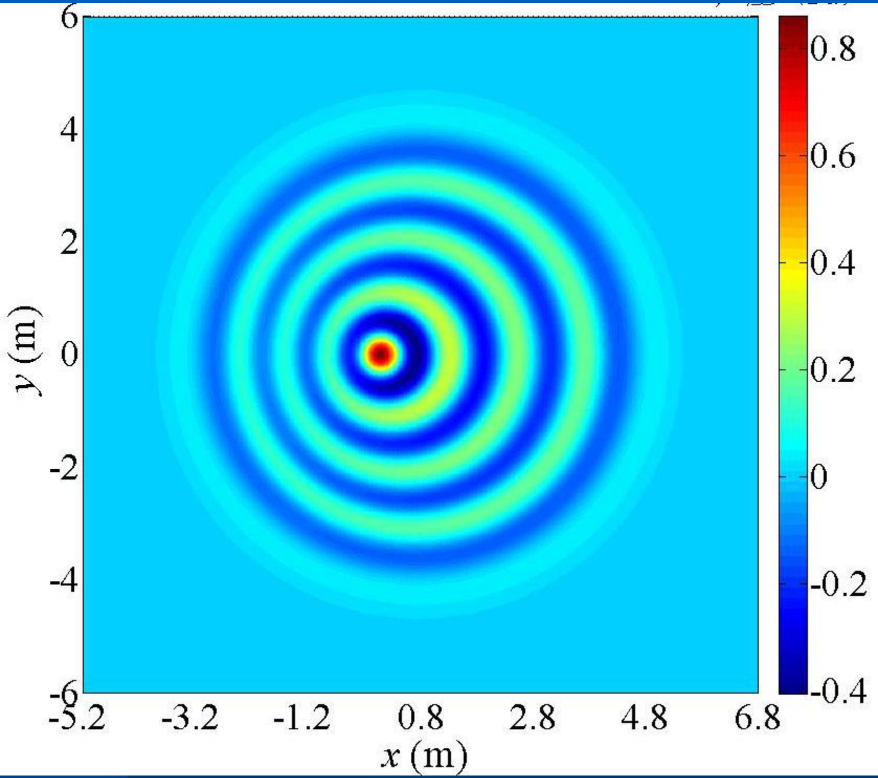




	r_s	x	Δx	ε_{RMS}	ε_{MAX}	CPU time (s)
CSPM	constant	[-0.5, 21.5]	0.01	0.0047	0.0223	208
FDPM	variable	[-0.5, 21.5]	0.05	0.0045	0.0166	196

Tests and Discussion

Test 3 sound propagation in mean flow (sound source)

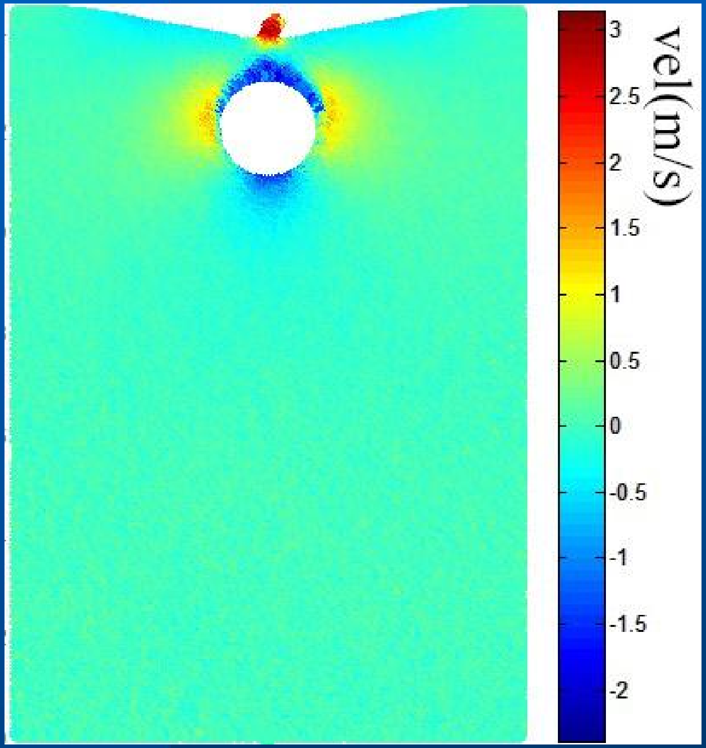


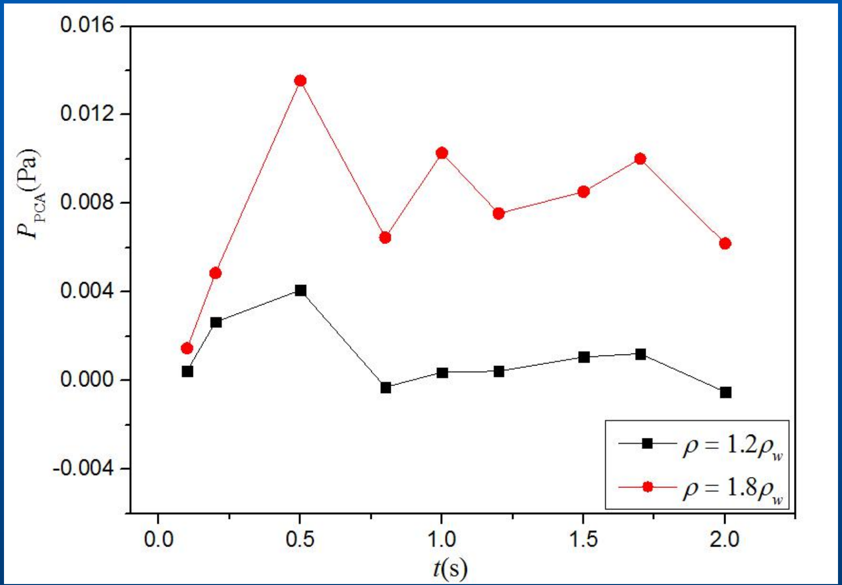
Sound pressure contour after 4.0 s propagation

Inlet flow comes from left with Mach number as 0.2

Tests and Discussion

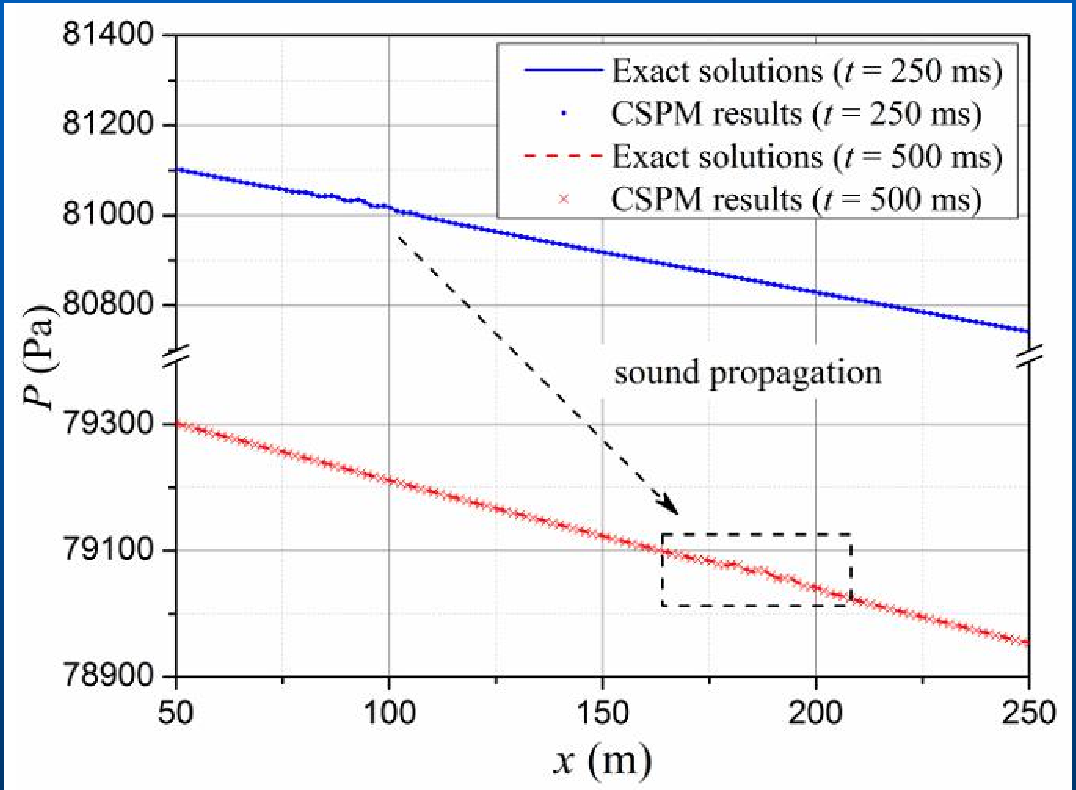
Test 4 Sound generation from rigid object falling into water





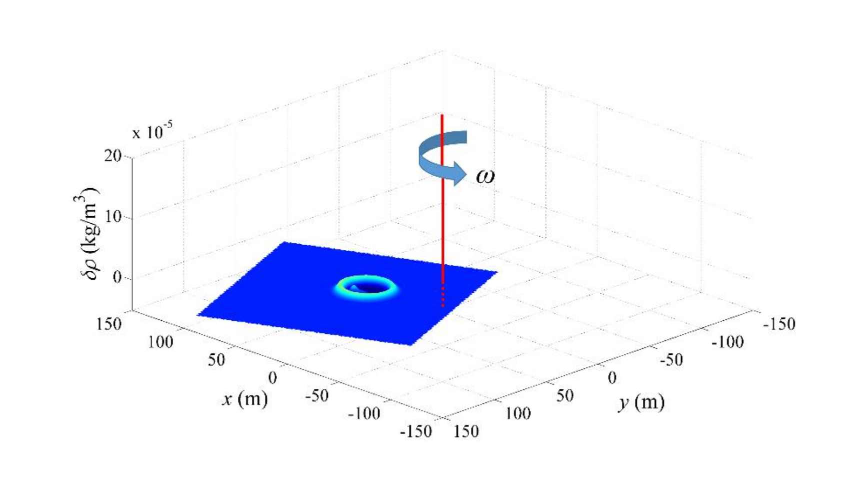
Tests and Discussion

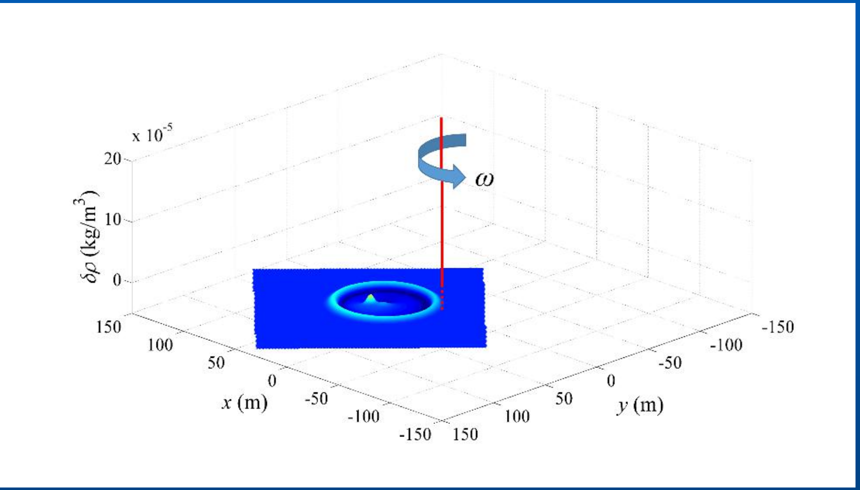
Test 5 sound propagation in pipeline (hybrid method)



Tests and Discussion

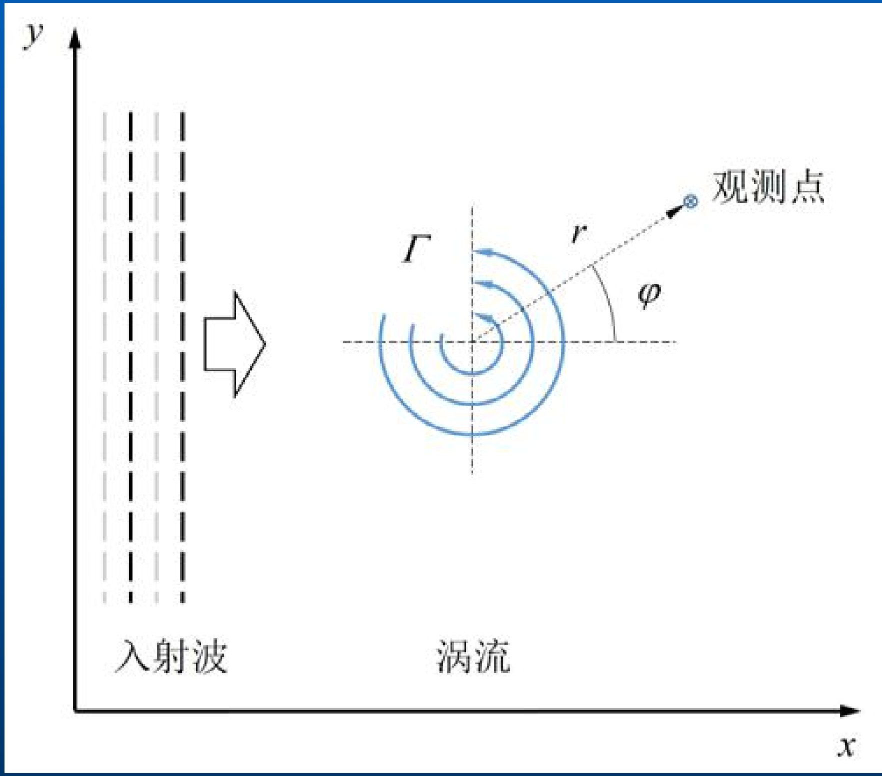
Test 6 sound propagation in vortex (hybrid method)





Tests and Discussion

Test 7 vortex scattering (hybrid method)



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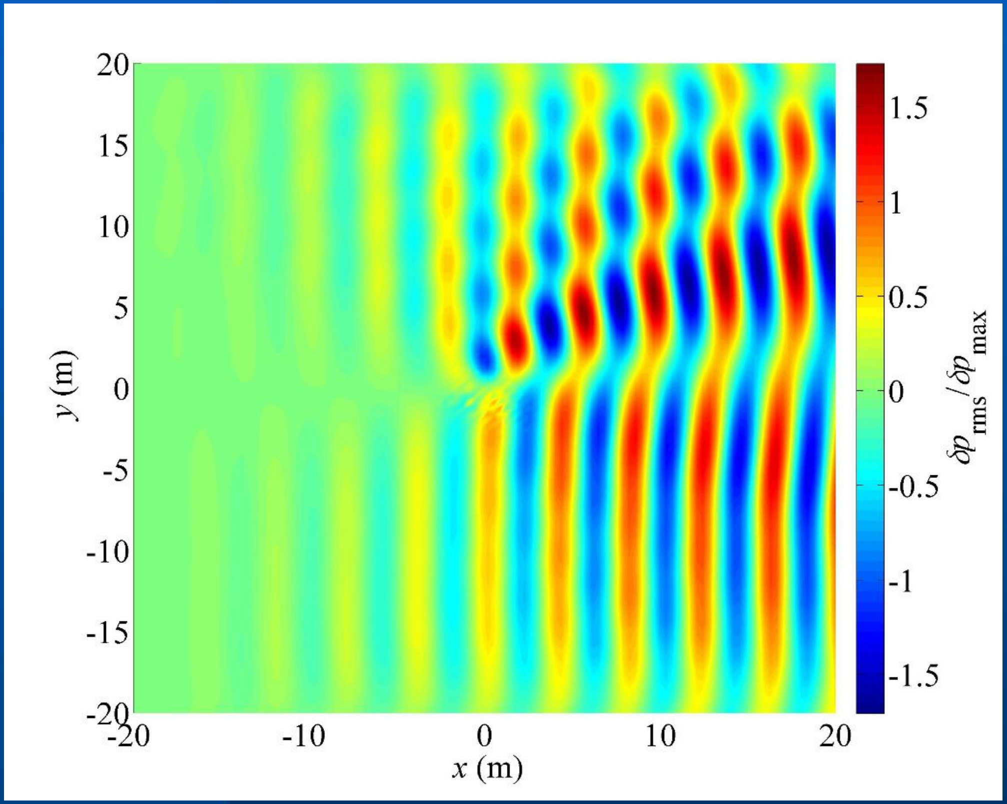

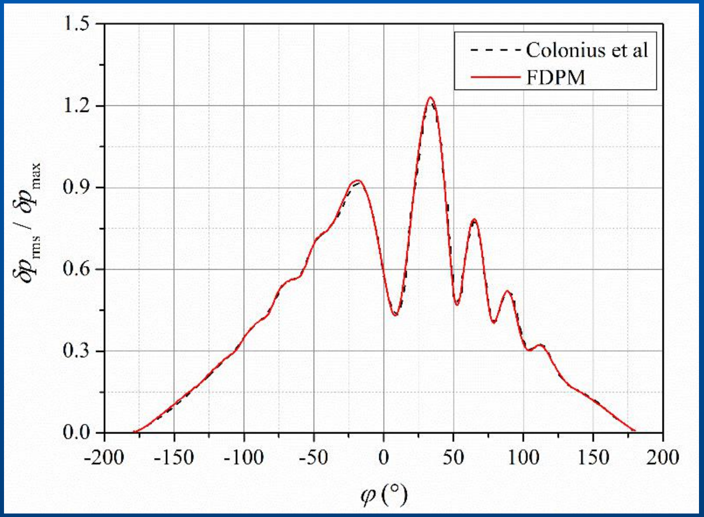

Future Work

I. Sound generation from rigid object falling into water;

II. Acoustic scattering from bubble flow;

III. Acoustic scattering from wake flow over an airfoil;

Thanks for your attention