The use of *CFD* in Hydroelastic Slamming

Marine Technology Gala

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Fluid-Solid Interaction in the Ocean

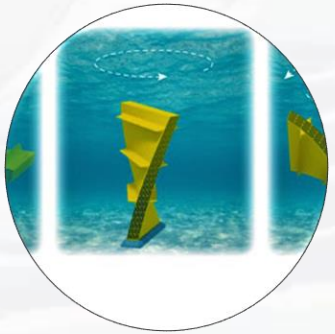
The mutual effects of water and solid on each other

Marine Vegetation
Coastal engineering

Ice covers in MIZ
Climate and Geophysics

Slamming
Marine Technology

Energy devices
Ocean Engineering



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Slamming

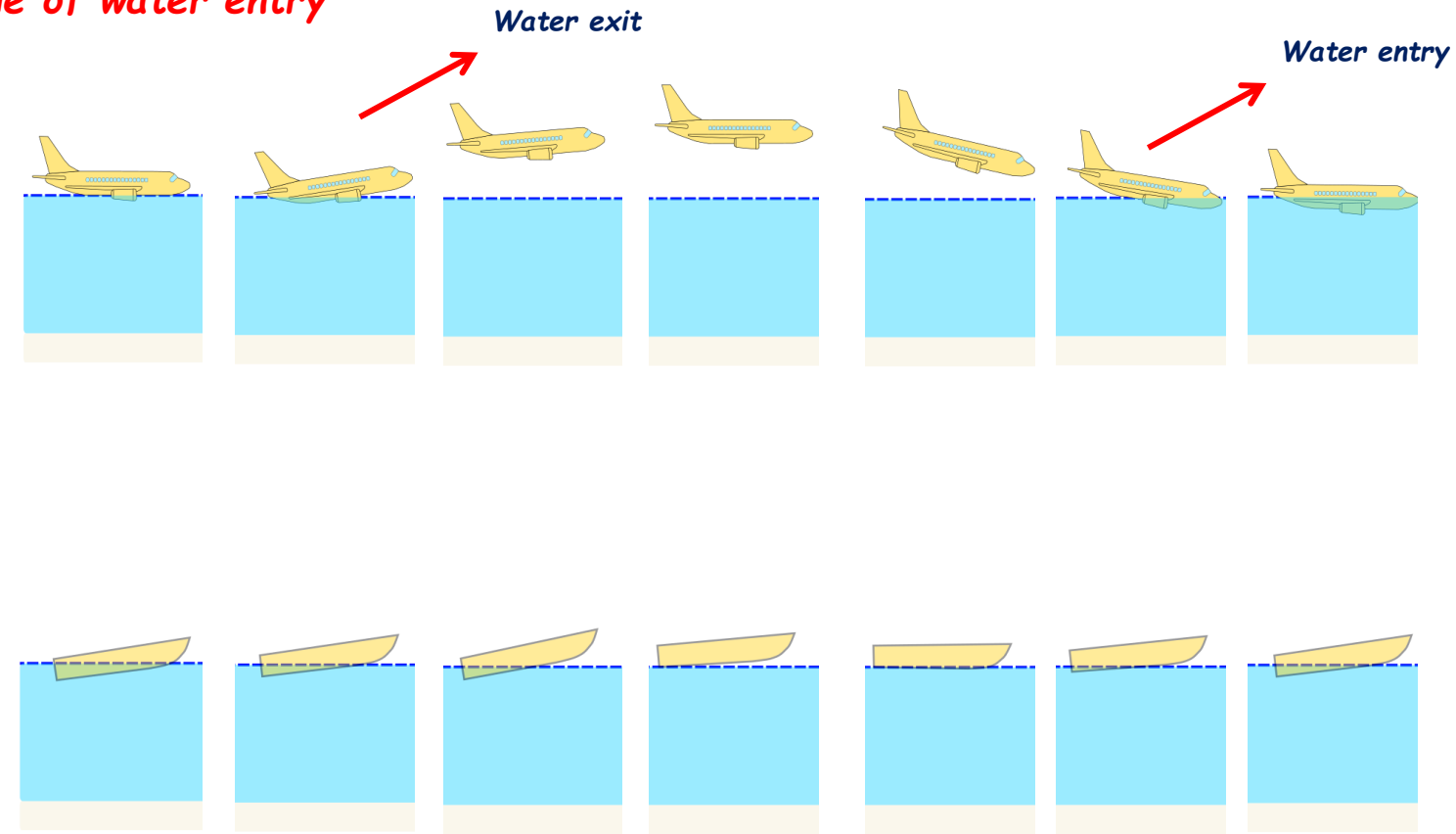
The water entering process of a solid object

Large loads

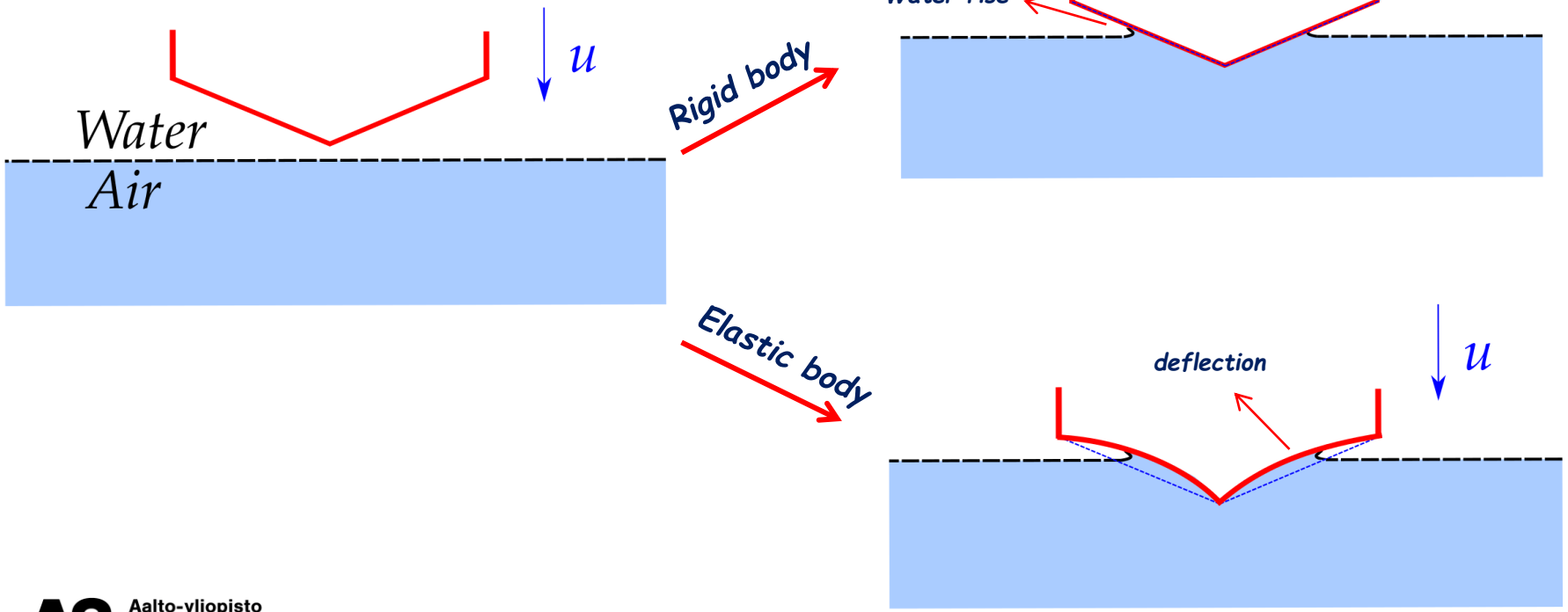
Structural damages

We want to predict the load and the resulting stresses!

Example of water entry

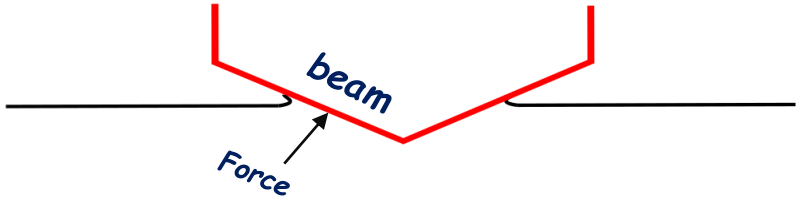


Hydroelastic water entry



How to solve the problem?

1) The classical approach



Fluid

Zero-viscosity assumption → Laplace equation

Boundary Integration Methods or Analytical solutions

Breaking process, and high-order nonlinear phenomena may not be well captures

Fluid domain

Fluid-solid interaction is treated by matching BCs

Solid

Plate/beam theories

FEA and modal analysis

How to solve the problem?

2) Viscous approach

Fluid

Viscous fluid → NS equations

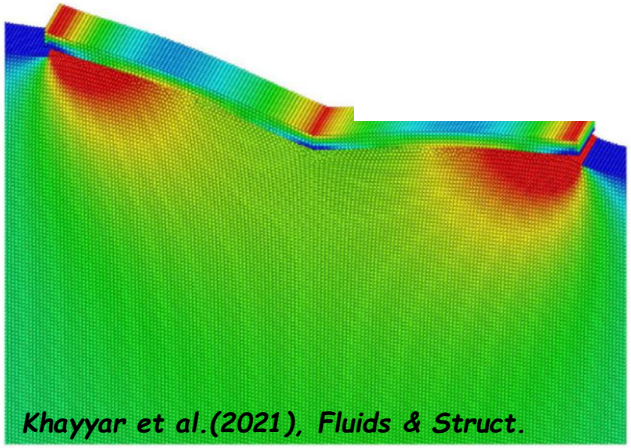
CFD or SPH methods

Fluid-solid interaction is treated by setting

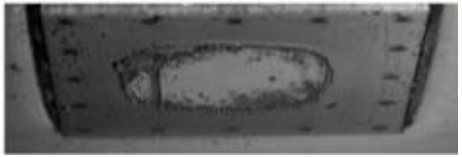
Solid

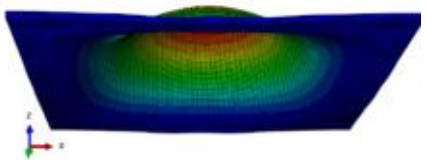
Plate/beam theories or continuum medium

FEA, Meshless, FVM



Khayyar et al.(2021), Fluids & Struct.



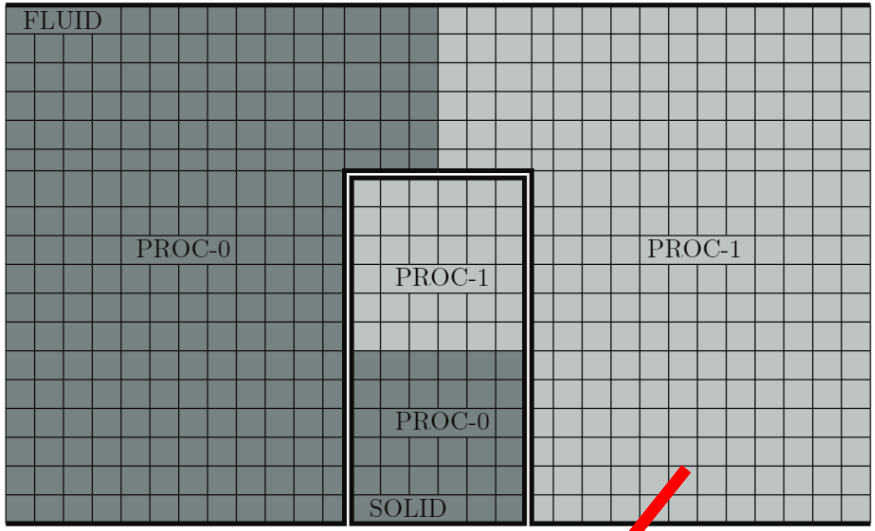


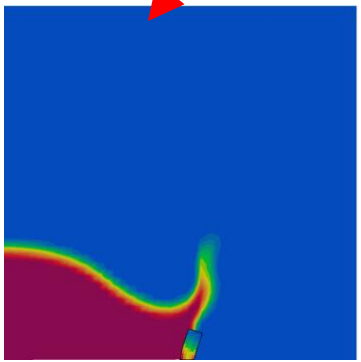
Yan et al.(2022), Marine Struct.

What happens if we use FVM to solve both problems

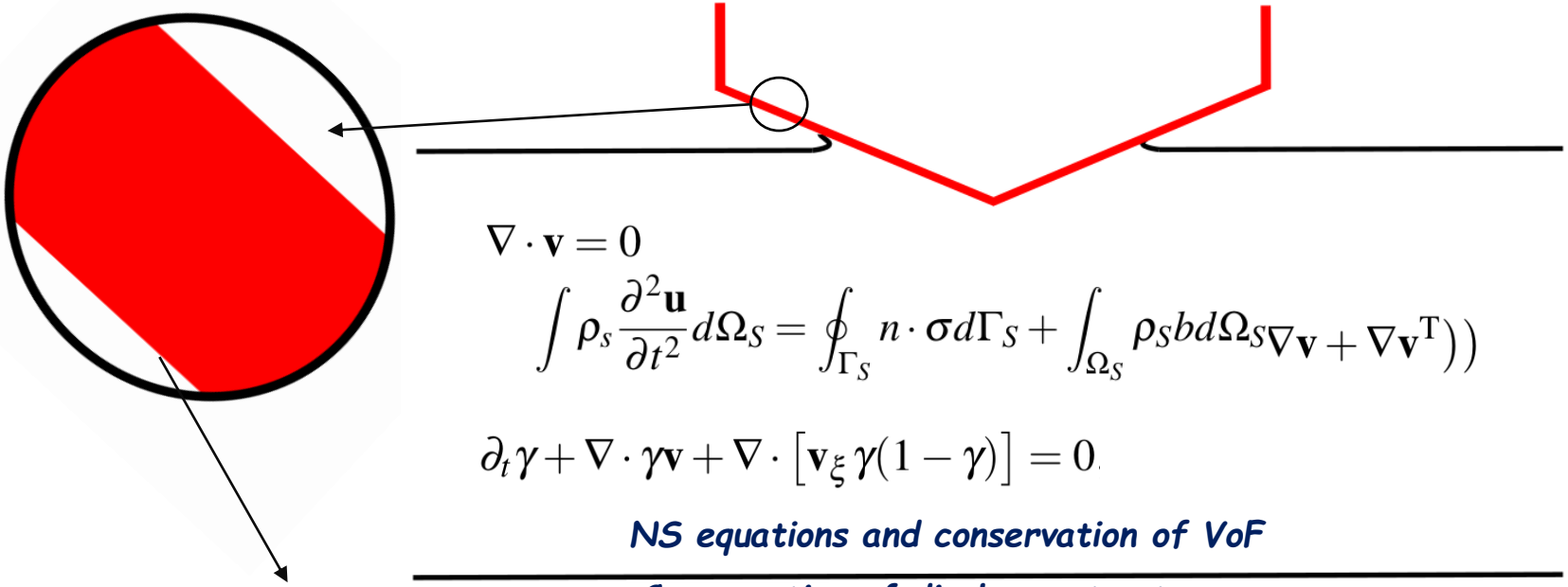
Cardiff (2022), 2nd CCP-WSI Hackathon

- Same decomposition method
- Faster simulations
- Better matching on FS interface
- Large strains can be monitored





Governing equations



$$\nabla \cdot \mathbf{v} = 0$$

$$\int \rho_s \frac{\partial^2 \mathbf{u}}{\partial t^2} d\Omega_S = \oint_{\Gamma_S} n \cdot \sigma d\Gamma_S + \int_{\Omega_S} \rho_S b d\Omega_S \nabla \mathbf{v} + \nabla \mathbf{v}^{\mathrm{T}}))$$

$$\partial_t \gamma + \nabla \cdot \gamma \mathbf{v} + \nabla \cdot \left[\mathbf{v}_\xi \gamma (1 - \gamma) \right] = 0$$

NS equations and conservation of VoF

Conservation of displacment rate

$$n_{FS} \cdot \sigma^+(x;t) = n_{FS} \cdot \sigma^-(x;t) \qquad \boldsymbol{u}(\boldsymbol{x};t)^+ = \boldsymbol{u}(\boldsymbol{x};t)^-$$

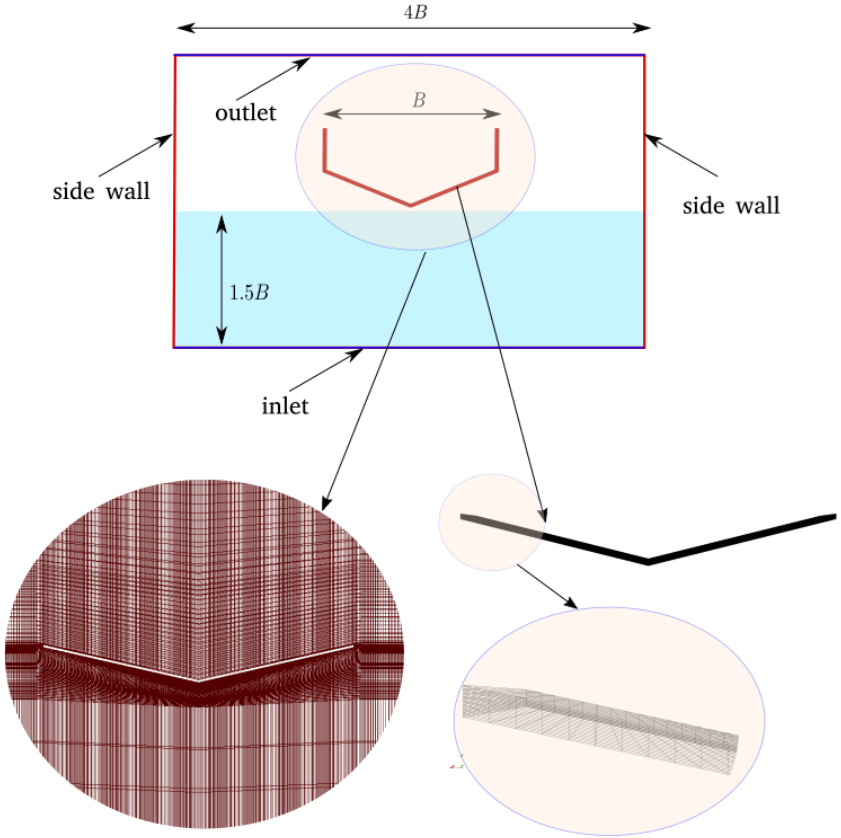
$$\boldsymbol{v}(\boldsymbol{x};t)^+ = \boldsymbol{v}(\boldsymbol{x};t)^-$$

Boundary conditions of FS interface

How do we set it up?

Fluid and solid domains are generated

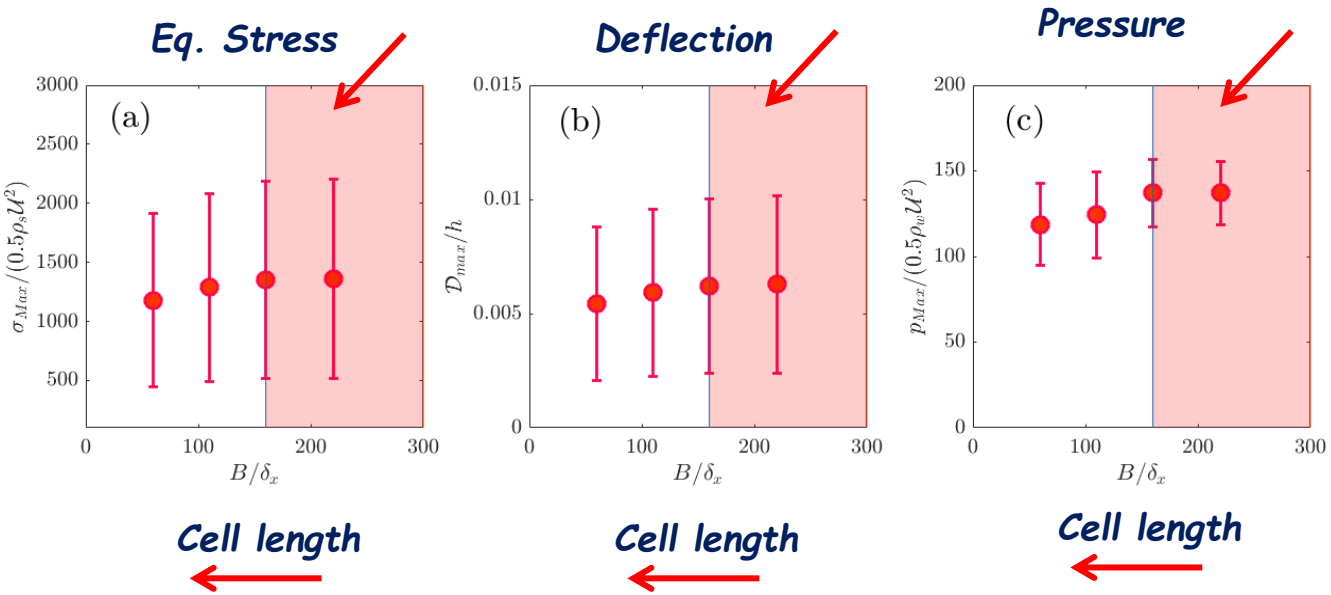
Fluid and solid domains are meshed



Mesh Study

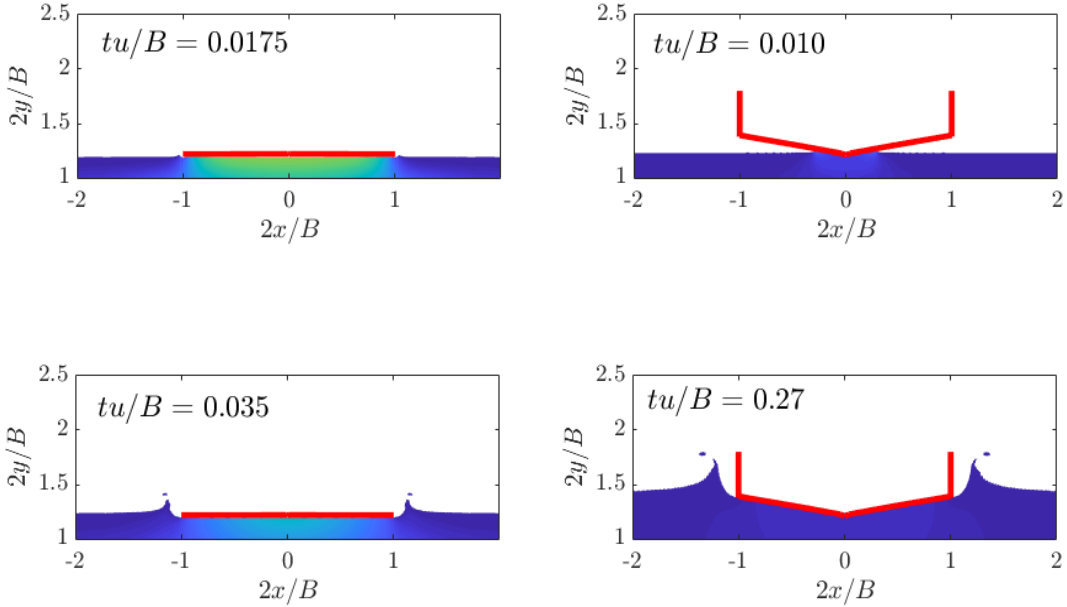
Average value

Standard variation



Snapshots of the pressure field

An elastic flat plate versus an elastic wedge

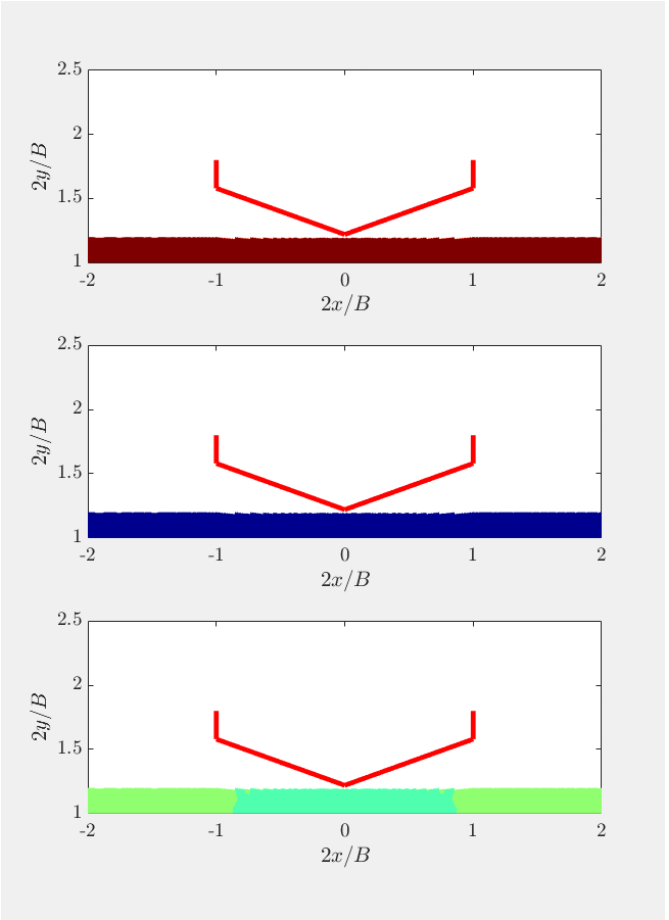


A demo of simulations

Water

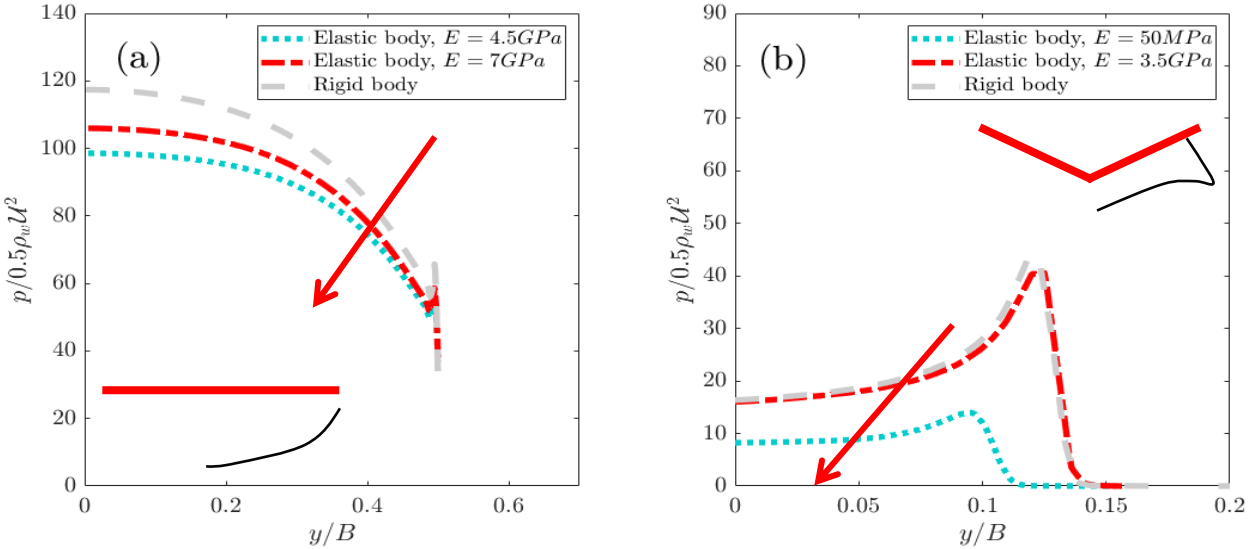
Pressure

Velocity



Does elasticity affect the pressure?

Pressure along the wall of plate or wedge

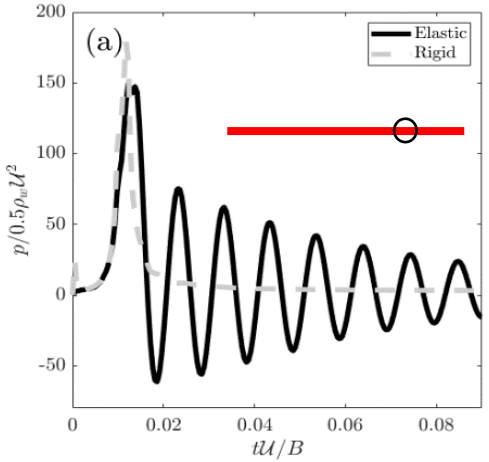


The pressure is reduced by the decrease in elastic modulus

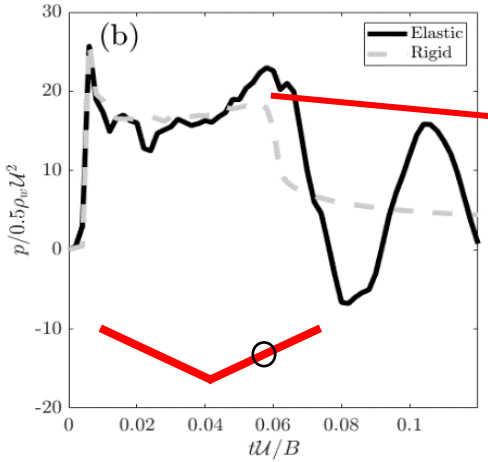
Does elasticity affect the pressure?

Time history of pressure at a point

plate



wedge



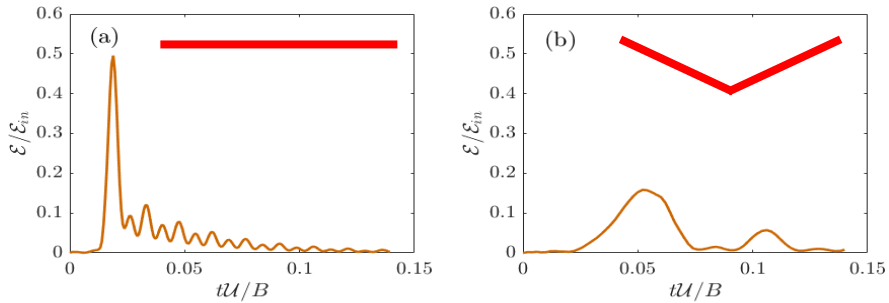
Fluid separation

The harmonic behavior observed is due to elastic motion of the solid body

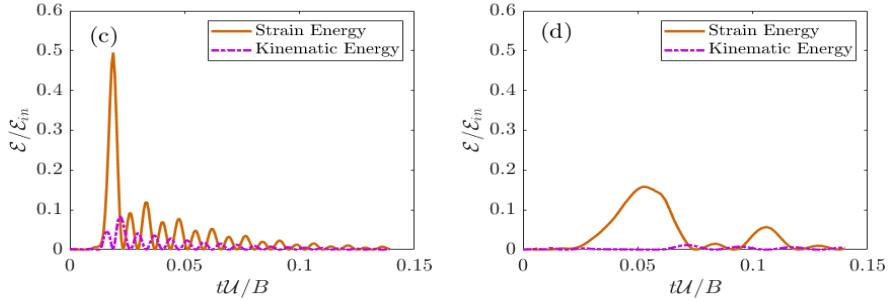
Energy arising in the solid body

plate **wedge**

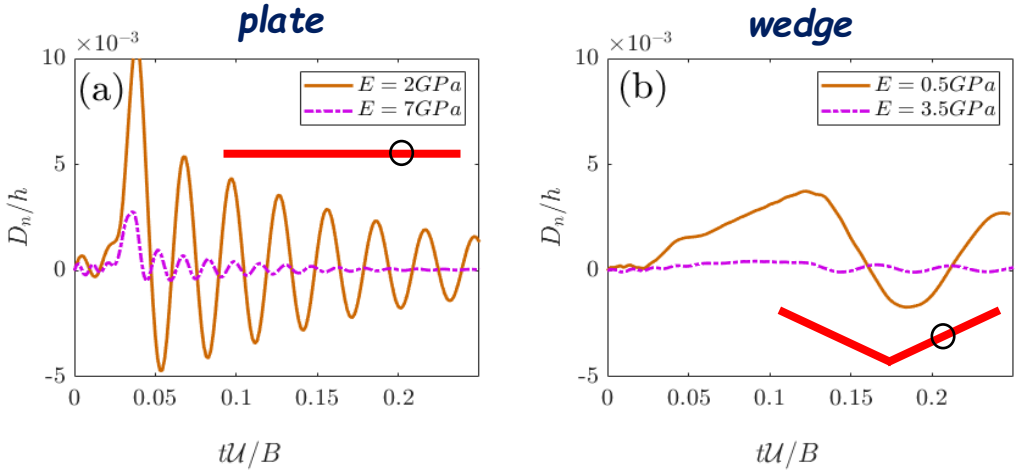
Total energy



Energy components



Displacement at the quarter point



Conclusions

- *FVM can be used for solving slamming problem, which is very fast!*
- *Flexible motion reduces the impact pressure.*
- *Strain energy is much larger than the kinematic energy.*

Thank you!