# NUMERICAL STUDY OF SURFACE TENSION INFLUENCE ON GLOBAL WAVE SHAPES BEFORE IMPACT USING FINITE ELEMENTS METHOD

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## CONTEXT

In fluid dynamics, sloshing refers to the movement of liquid inside a container which is usually oscillating. This phenomenon is important to consider in marine engineering for example LNG (Liquid Natural Gas) carriers as it could be endangering the safety of the carrier. In order to capture the fluid-structure interaction, sloshing model tests are performed at a smaller scale in accordance with Froude similarity.

The influence of tension surface on the global wave shape before impact is studied through numerical simulations.

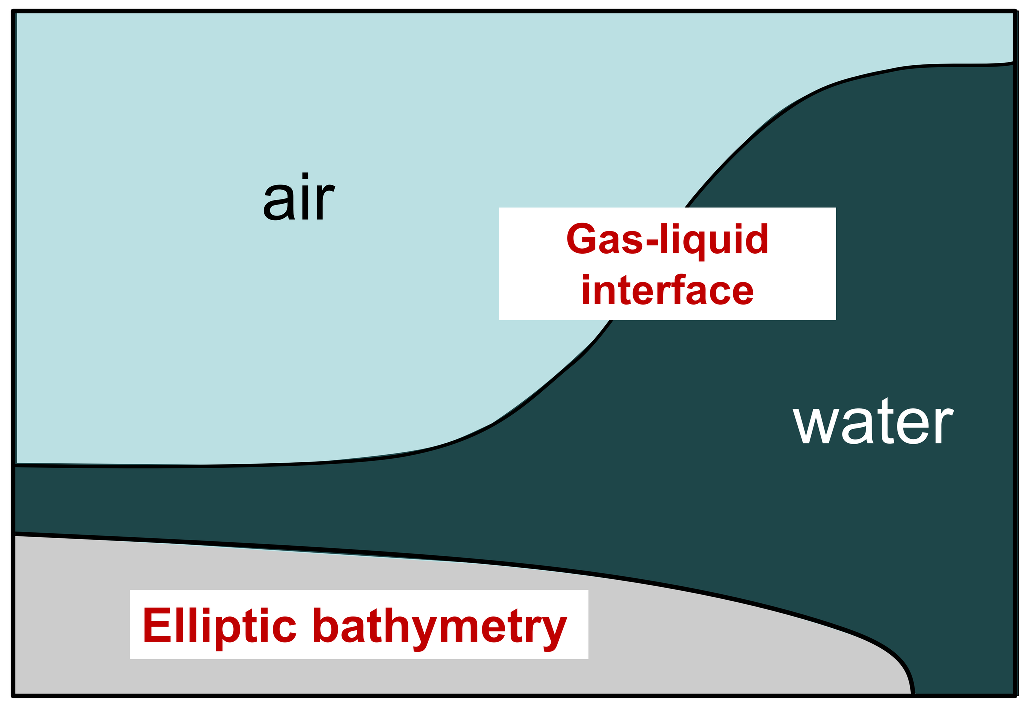
Previous studies on the transfer of energies between the two phases have shown the decay of total mechanical energy (potential + kinetic) of the liquid and gas.

The current study focuses on understanding the contribution of surface tension and viscous dissipation to this decay.

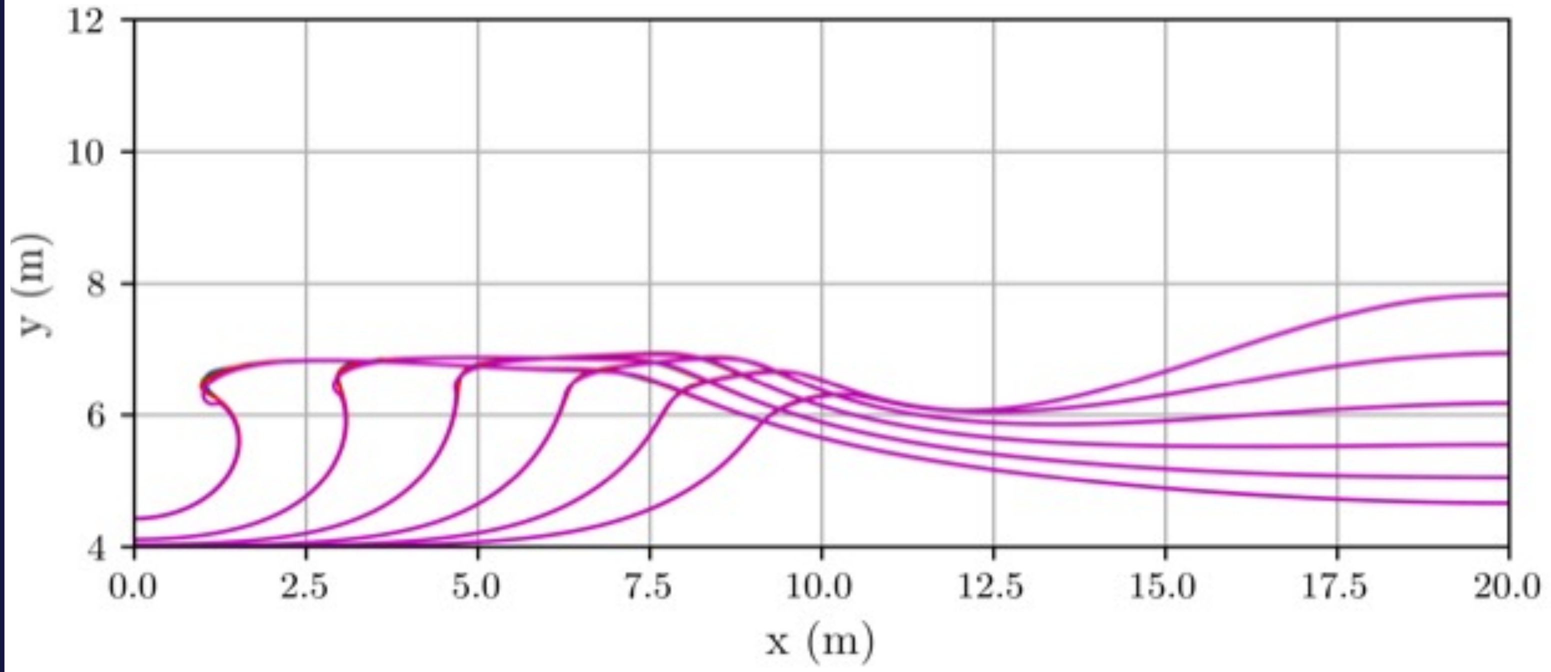
## FINITE ELEMENT CODE: CADYF

Developed by Ecole Polytechnique of Montreal (EPM), CADYF is a high-precision front-tracking solver of the Navier-Stokes equations simulating separated viscous two-phase flows with surface tension. Adaptivity in space (adaptive remeshing) and time (hp-adaptivity) enables to yield accurate predictions while keeping computational cost low.

## DEFINITION OF CALCULATION CASE




Evolution in time of the global wave shape




## OBJECTIVES

- Understand the effect of surface tension on the exchange of energies between the liquid and gas,
- Compute the viscous dissipation energy in the domain.

## SURFACE TENSION CALCULATION CASES

The surface tension for $case^{\sigma}_{\lambda_s}$ is defined as follow: $\sigma_\lambda = (\frac{\lambda}{40})^2 \sigma_{40}$

| | $case^{\sigma}_{1}$ | $case^{\sigma}_{10}$ | $case^{\sigma}_{20}$ | $case^{\sigma}_{40}$ |
|---|---|---|---|---|
| Surface tension* ($N.m^{-1}$) | $4.550\ 10^{-5}$ | $4.550\ 10^{-3}$ | $1.820\ 10^{-2}$ | $7.280\ 10^{-2}$ |

*Surface tension at the interface between water and gas

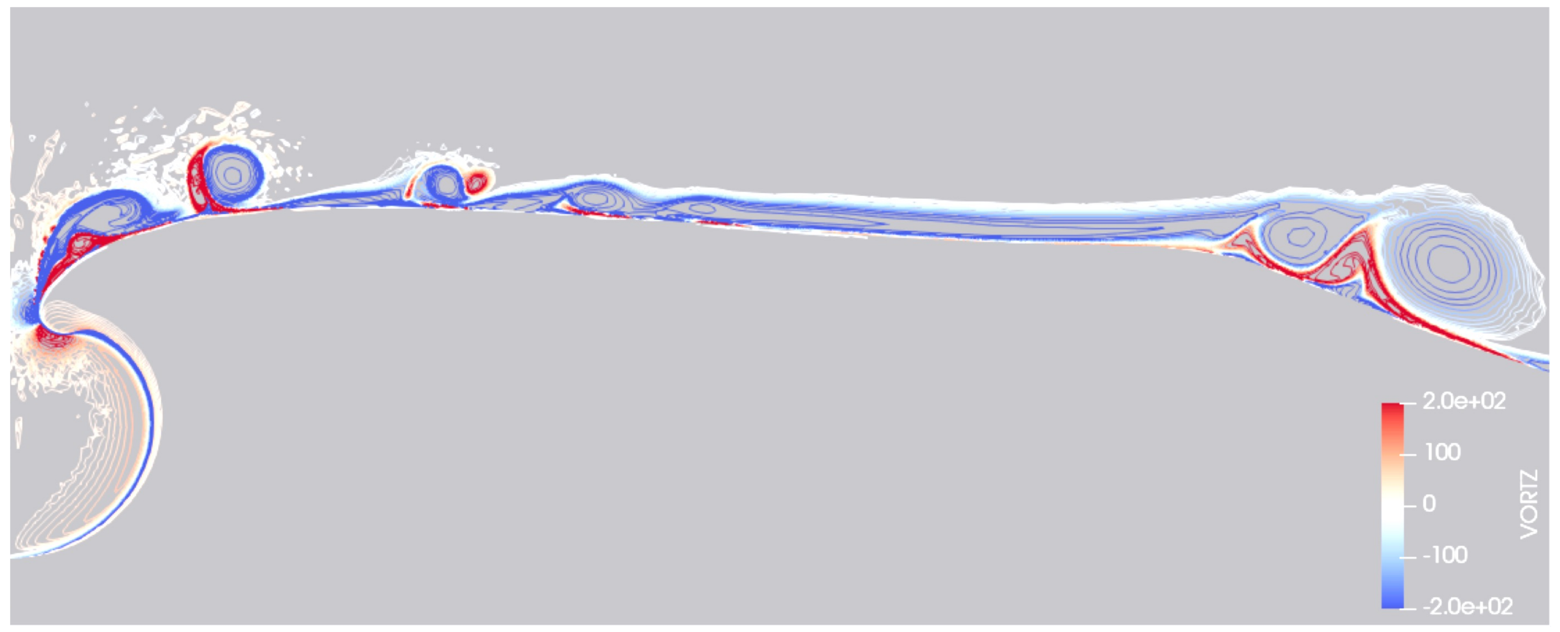
## VARIABLES

$E^l_p$ potential energy into the liquid,
$E^l_k$ kinetic energy into the liquid,
$E^g_p$ potential energy into the gas,
$E^g_k$ kinetic energy into the gas,
$E^l_m = E^l_p + E^l_k$ liquid mechanical energy,
$E^g_m = E^g_p + E^g_k$ gas mechanical energy,
$E_\mu$ viscous dissipation energy

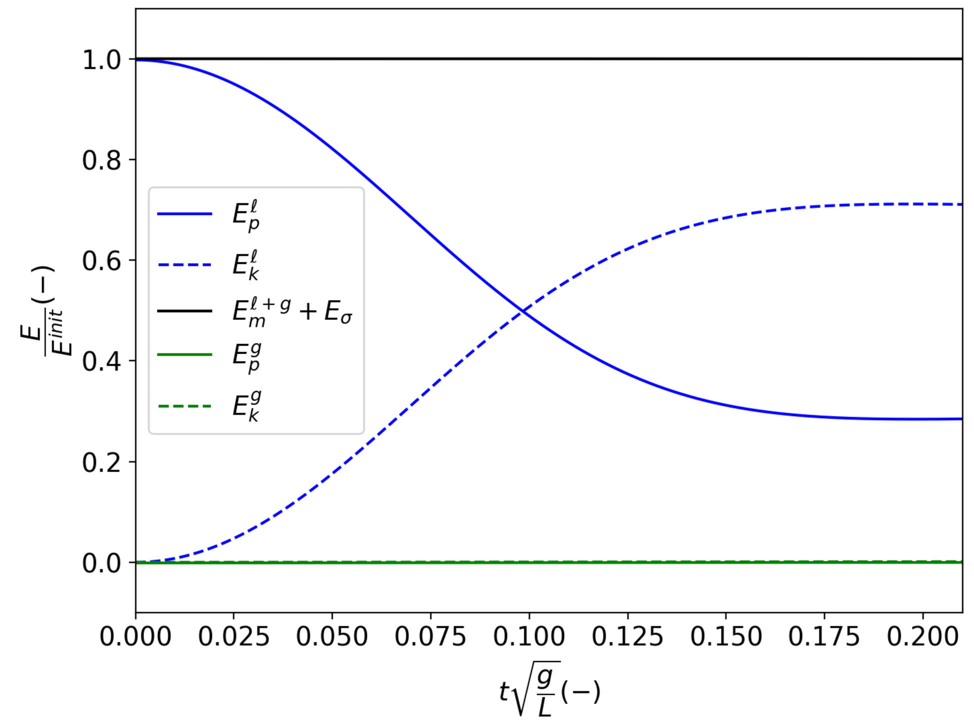
$E_p = E^l_p + E^g_p$ total potential energy,
$E_k = E^l_k + E^g_k$ total kinetic energy,
$E_m = E_p + E_k$ total mechanical energy,
$E^{l:interf}_m$ mechanical energy transferred at the interface to the liquid,
$E^{g:interf}_m$ mechanical energy transferred at the interface to the gas,
$E_\sigma$ surface tension energy.

## RESULTS

Vorticity distribution before impact for $case^{\sigma}_{40}$

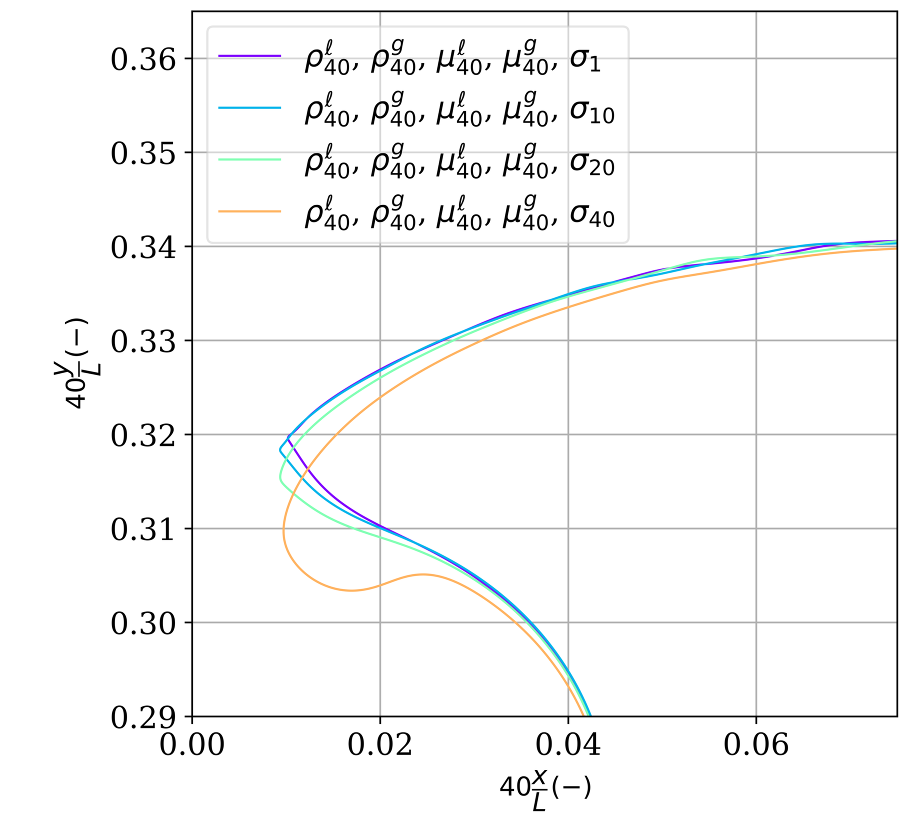



Energy balance of the liquid and gas for $case^{\sigma}_{40}$

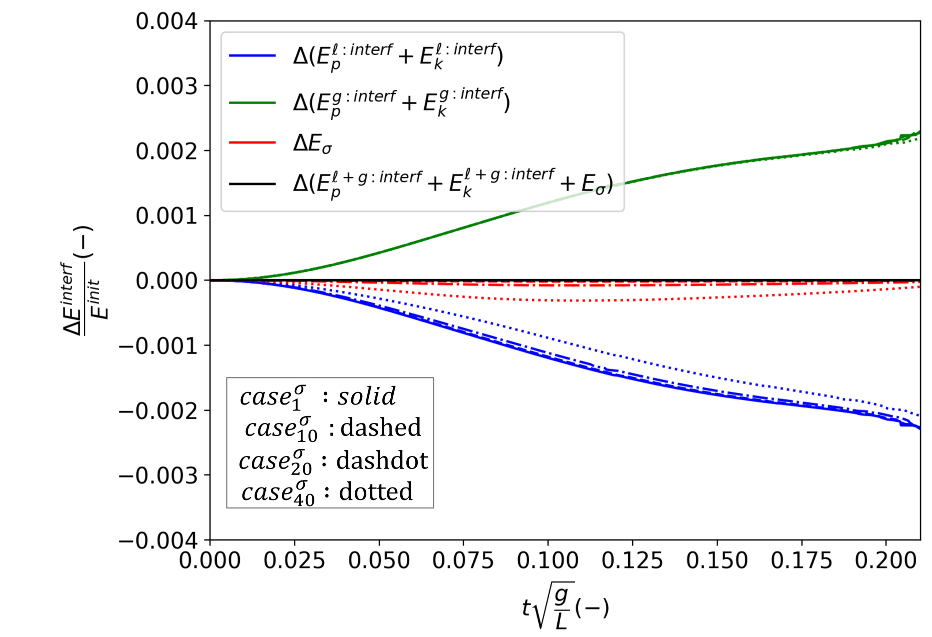


## RESULTS (CONT'D)

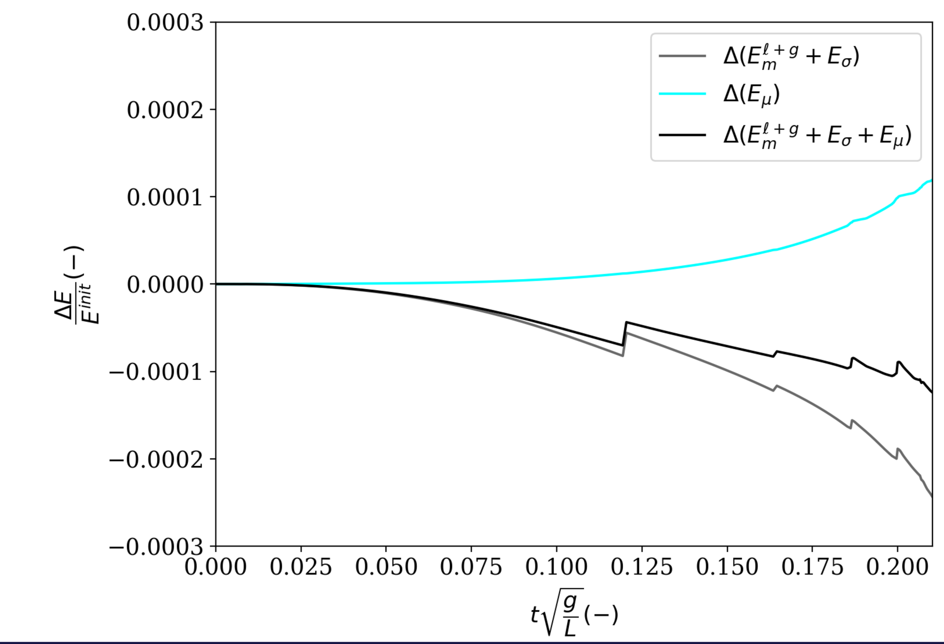
Effect of surface tension on the global shape of the waves before impact



Variation of mechanical energy transferred at the interface, of surface tension energy and of total energy of the system




Effect of viscous dissipation on variation of the system's total energy



## CONCLUSIONS

- Surface tension modifies the global shape of the wave,
- Mechanical energy is transferred from the liquid to the gas, its magnitude decreases with surface tension,
- Variation of total mechanical and surface tension energies decreases with time due to viscous and numerical dissipation.

## ACKNOWLEDGMENTS

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