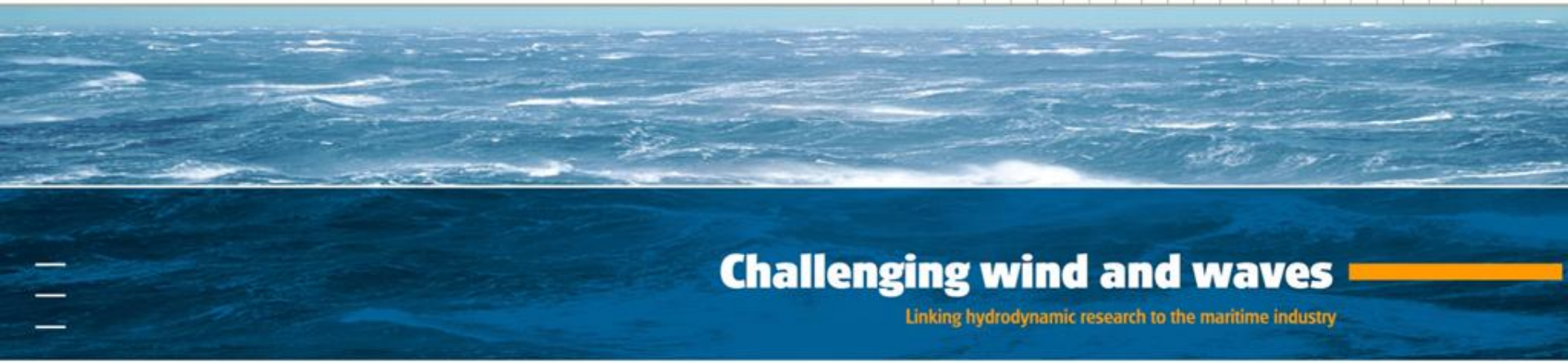
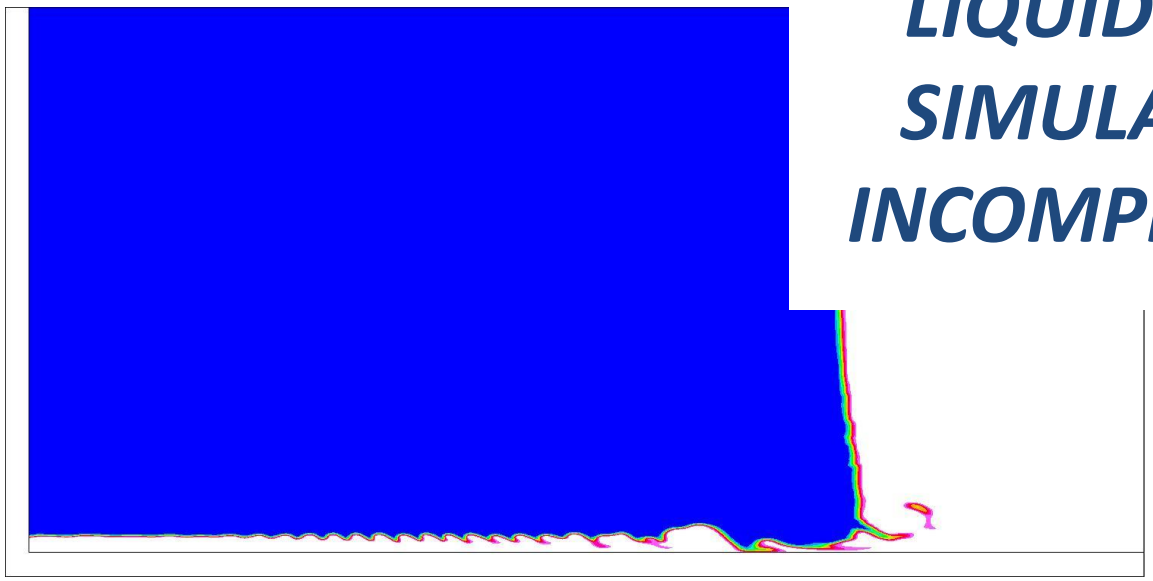
MARIN





LIQUID PATCH IMPACT SIMULATION WITH AN INCOMPRESSIBLE SOLVER

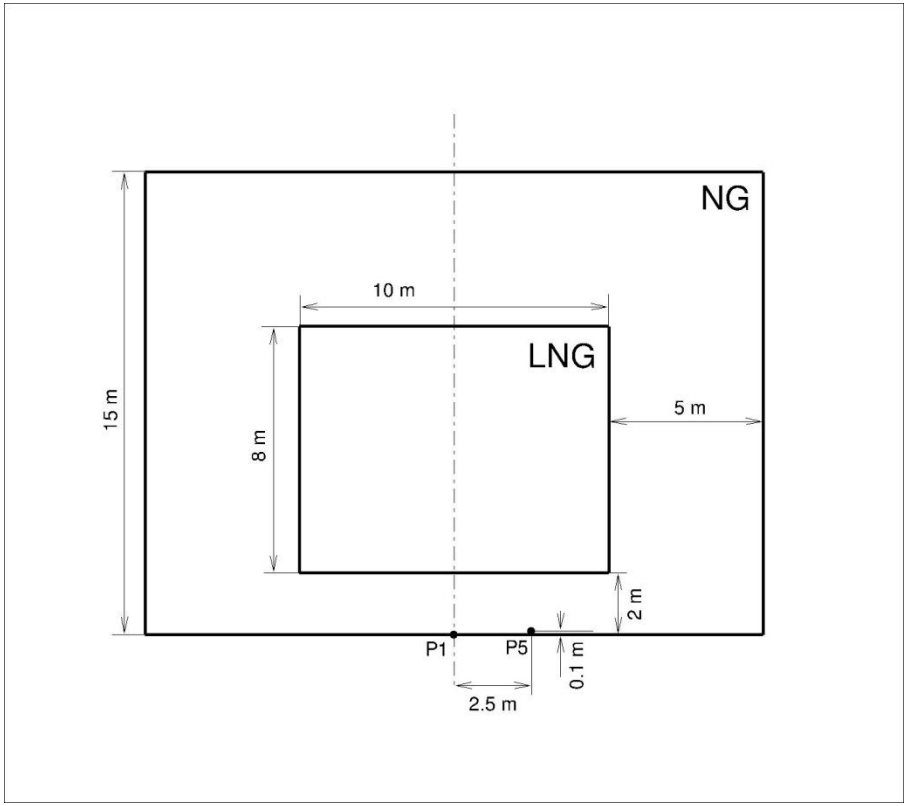
Jaap Windt

LIQUID IMPACT

- Introduction of the liquid patch test case
- Numerical settings
- Initial study
  - Grid dependency
  - Time-step dependency
  - Numerical uncertainty
- Extended grid study
- Conclusions & future work

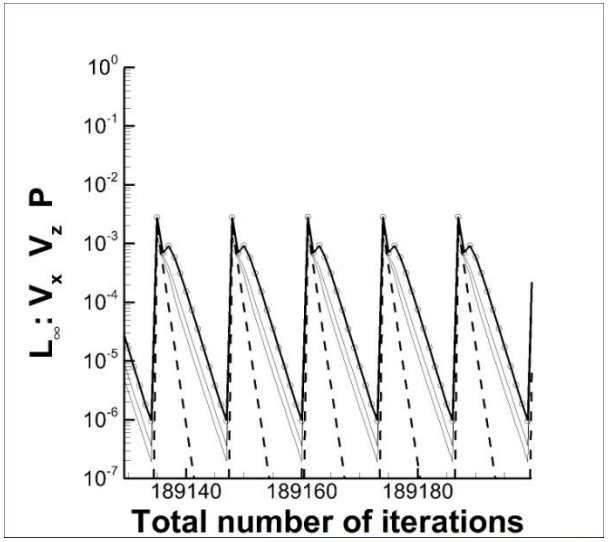
LIQUID PATCH

- 2D free drop of a rectangular liquid patch
- Scale 1:1
- LNG: 455 kg/m^3
- NG : 1.82 kg/m^3
- Dynamic viscosity 10^{-12} Pa s
- Incompressible
- No surface tension



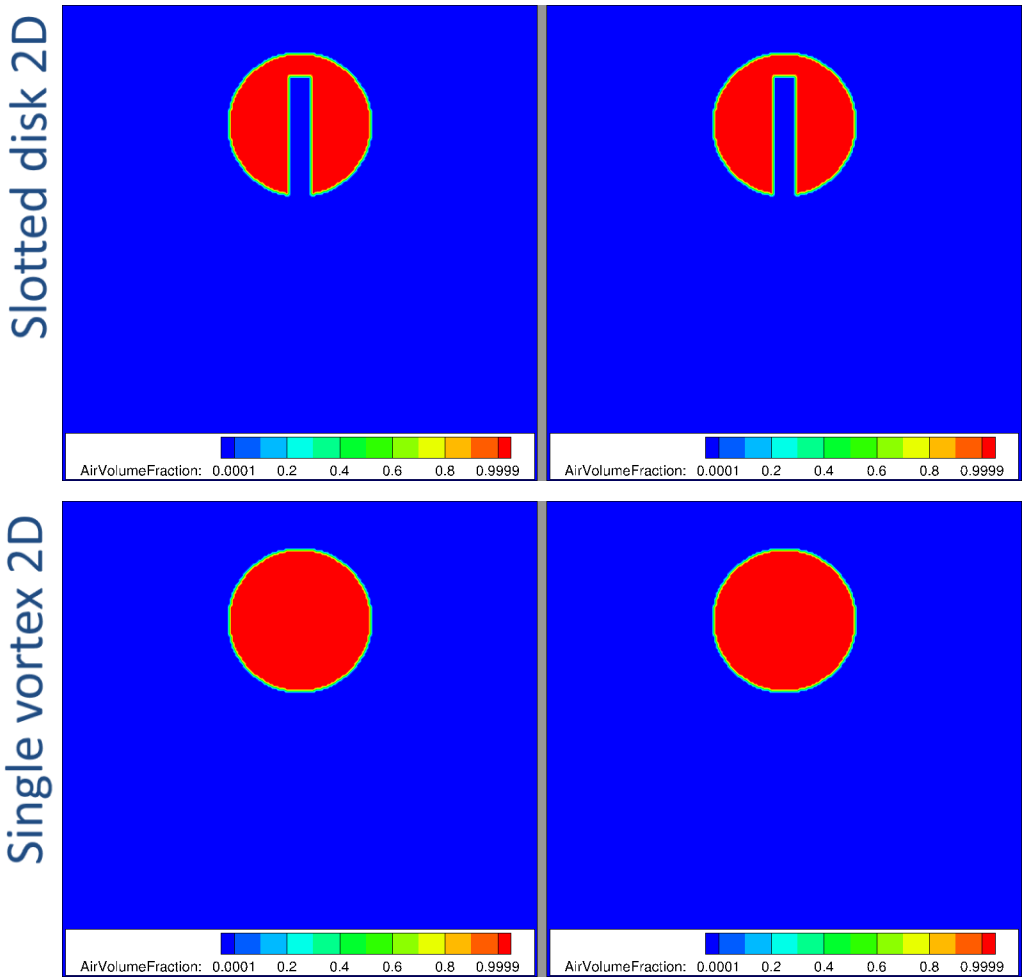
NUMERICAL SETTINGS

- Flow solver ReFRESCO
- Time discretisation: implicit Euler
- Transport of VOF, convective flux discretisation
  - HRIC: High resolution interface capturing scheme
  - REFRICS: ReFRESCO interface capturing scheme
- Strict convergence per time-step
  - Low iterative error



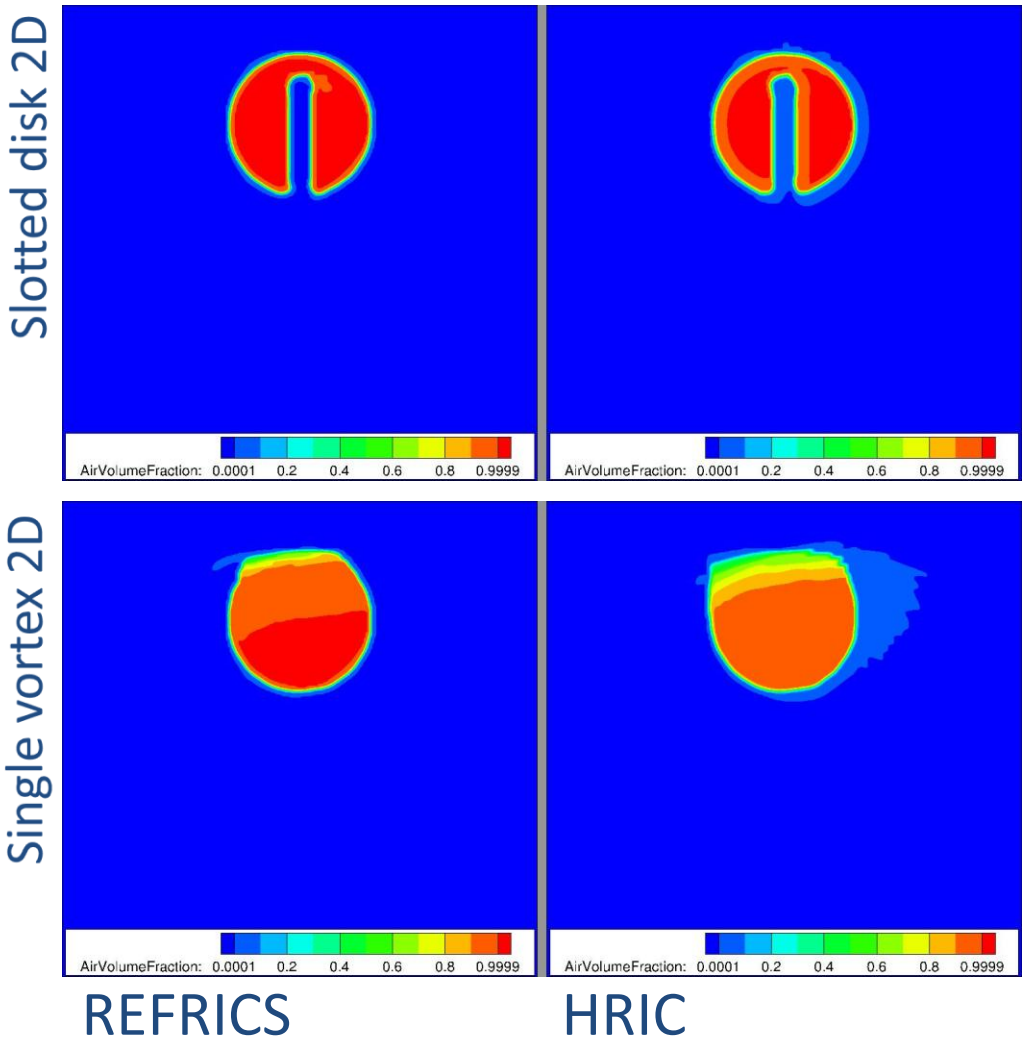
INITIAL STUDY

- 3 grids
  - 160x240x1
  - 320x480x1
  - 640x960x1
- 3 time-step sizes
  - 0.08 ms
  - 0.04 ms
  - 0.02 ms
- 2 discretisation schemes
  - HRIC
  - REFRICS



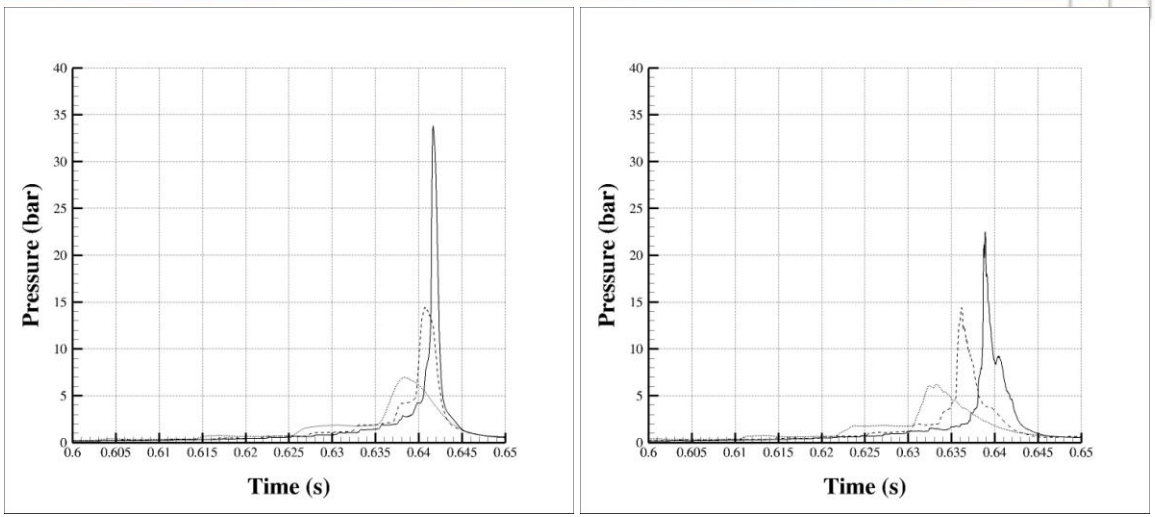
INITIAL STUDY

- 3 grids
  - 160x120x1
  - 320x240x1
  - 640x480x1
- 3 time-step sizes
  - 0.08 ms
  - 0.04 ms
  - 0.02 ms
- 2 discretisation schemes
  - HRIC
  - REFRICS

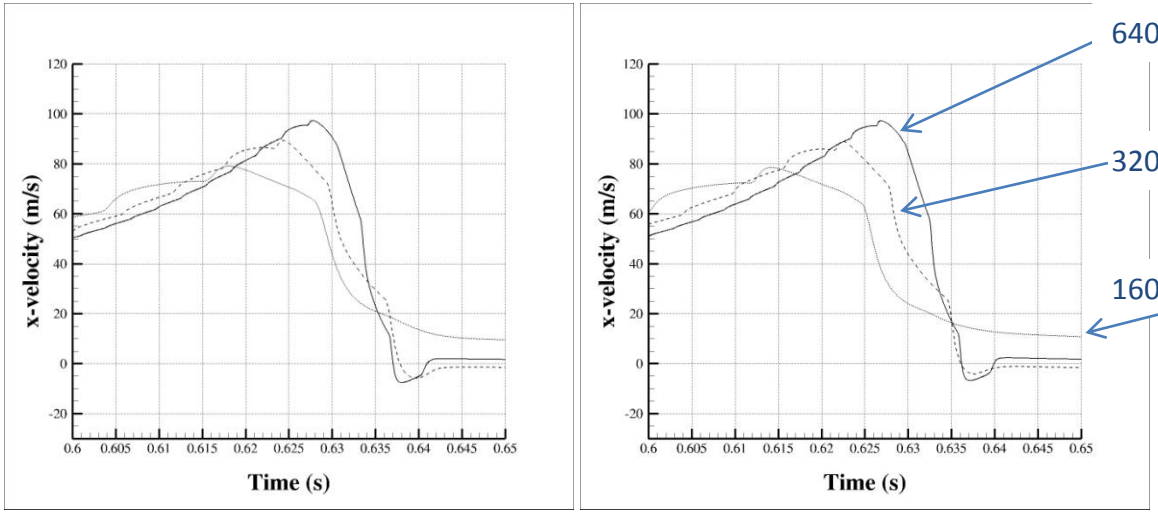


INITIAL STUDY

Pressure in P1



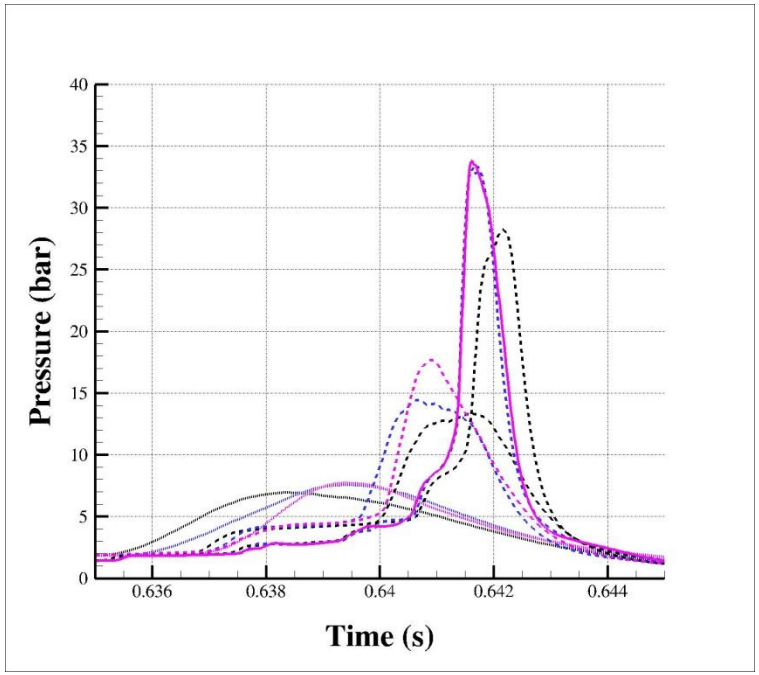
X-velocity in P5



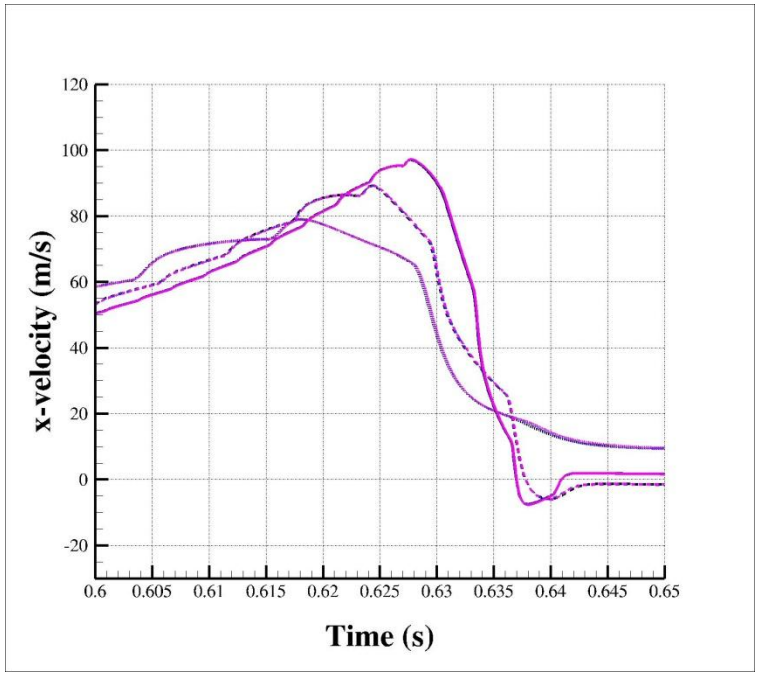
REFRICS HRIC

INITIAL STUDY

- Influence time-step (REFRICS)
  - grid dependency >> time-step dependency
  - Influence on x-velocity negligible



Pressure in P1

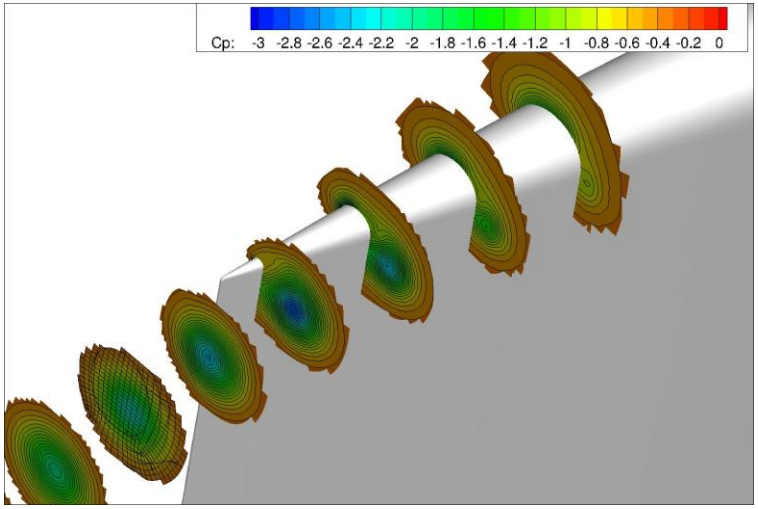


X-velocity in P5

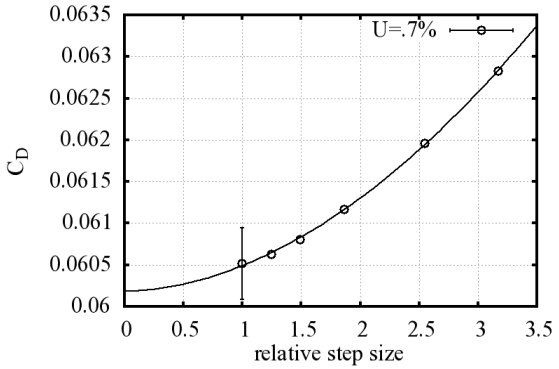
INITIAL STUDY

* http://www.refresco.org/verification-validation/utilitiesvv-tools/

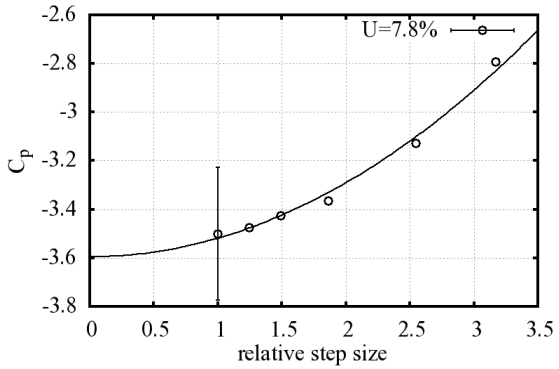
- Numerical uncertainty following Eça and Hoekstra*
  - Steady flow, NACA wing example: 0.9M to 29.9M cells



Pressure in vortex core



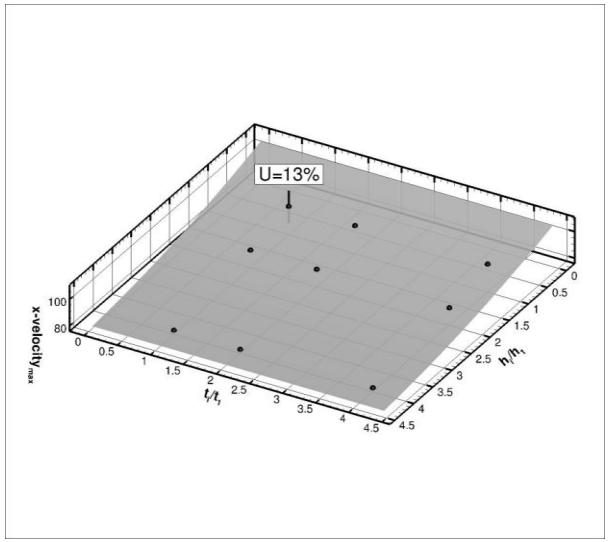
Wing drag



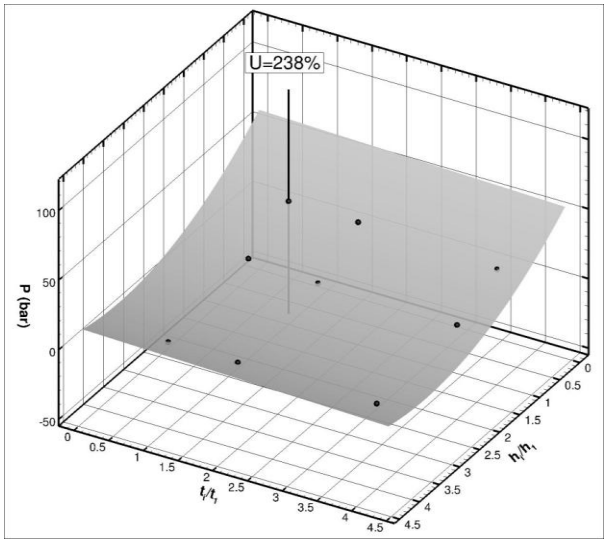
Minimum pressure in vortex

INITIAL STUDY

- Numerical uncertainty
  - grid dependency >> time-step dependency
  - Maximum x-velocity in P5: 97.2 ± 12.6 m/s (U=13%)
  - Maximum pressure in P1: 33.8 ± 80.4 bar (U=238%)



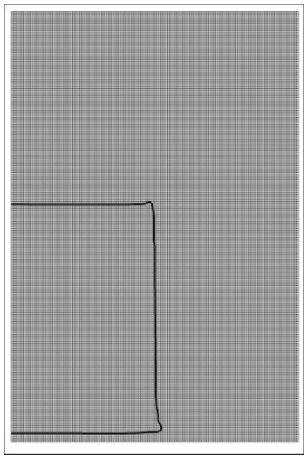
Maximum x-velocity in P5

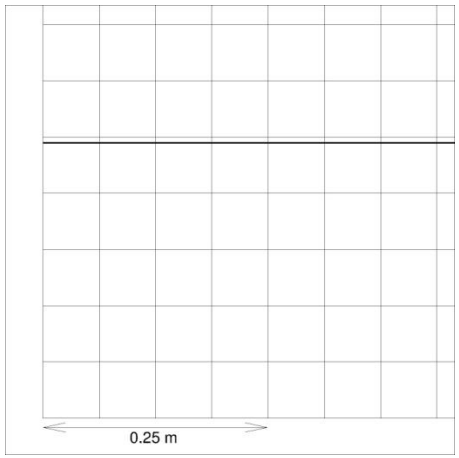


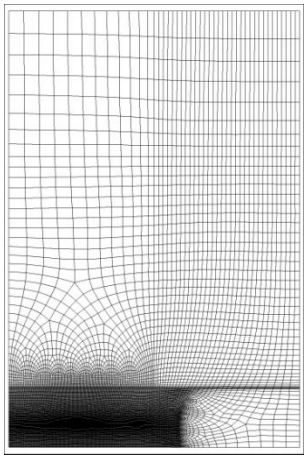
Maximum pressure in P1

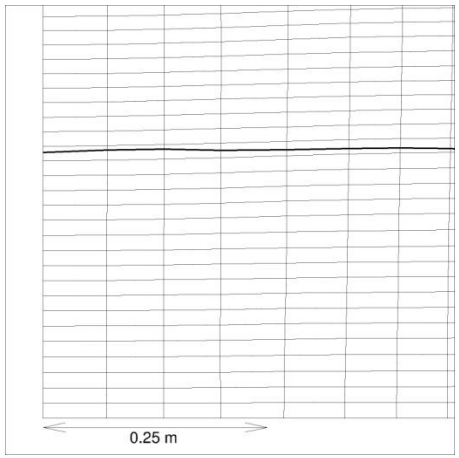
EXTENDED GRID STUDY

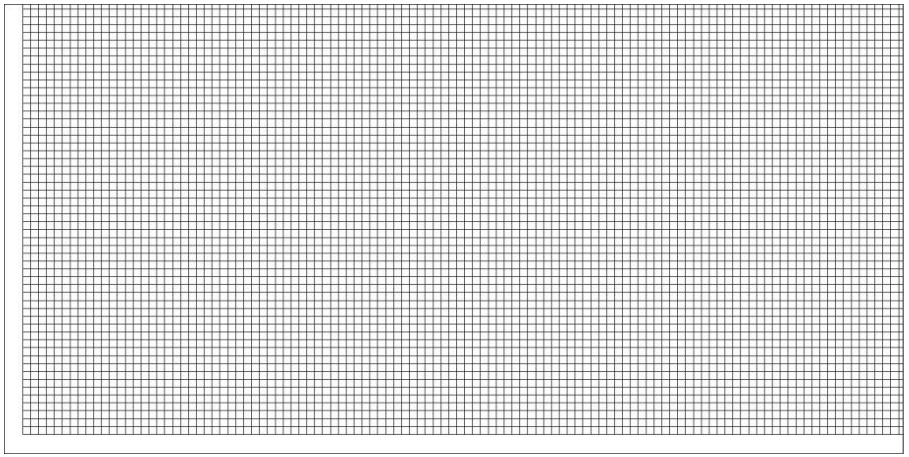
- Use multi-block structured mesh to increase resolution

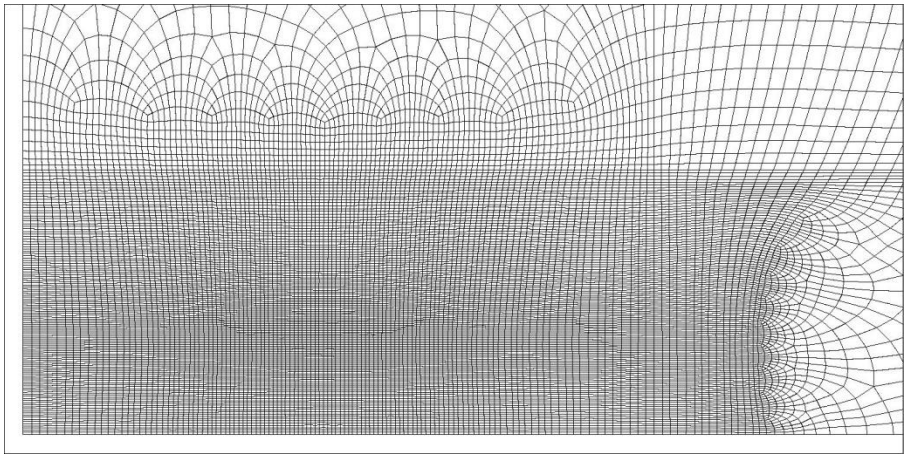












160x240: 38,400 cells

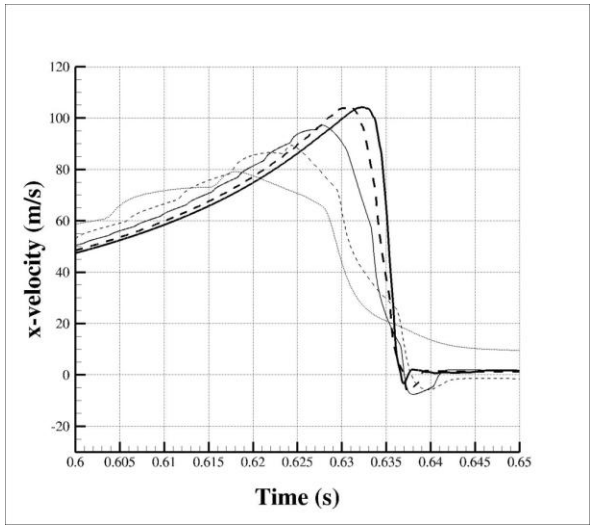
GridD32: 19,424 cells

EXTENDED GRID STUDY

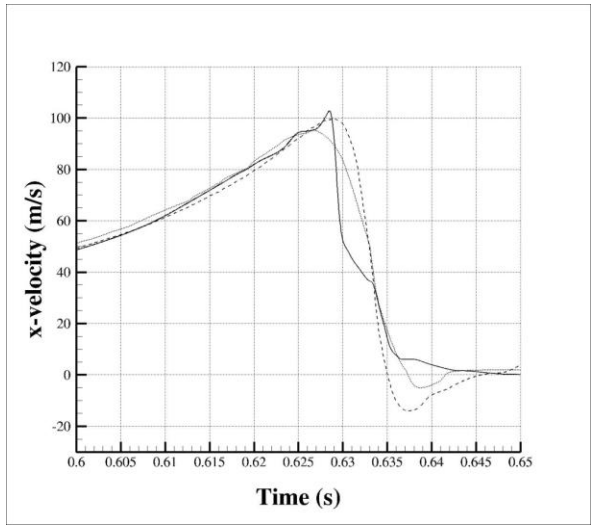
- 5 new grids
  - 2 extra Cartesian grids:
    - 1280x1920: 2,457,600 cells $\Delta t = 0.01$ ms
    - 2560x3840: 9,830,400 cells $\Delta t = 0.005$ ms
  - 3 Multi-block structured grids
    - 19,424 cells $\Delta t = 0.08$ ms
    - 77,696 cells $\Delta t = 0.04$ ms
    - 310,784 cells $\Delta t = 0.02$ ms

EXTENDED GRID STUDY

- x-velocity in P5
  - Solution on Cartesian mesh shows consistent results
  - Solution on multi-block structured mesh slightly different



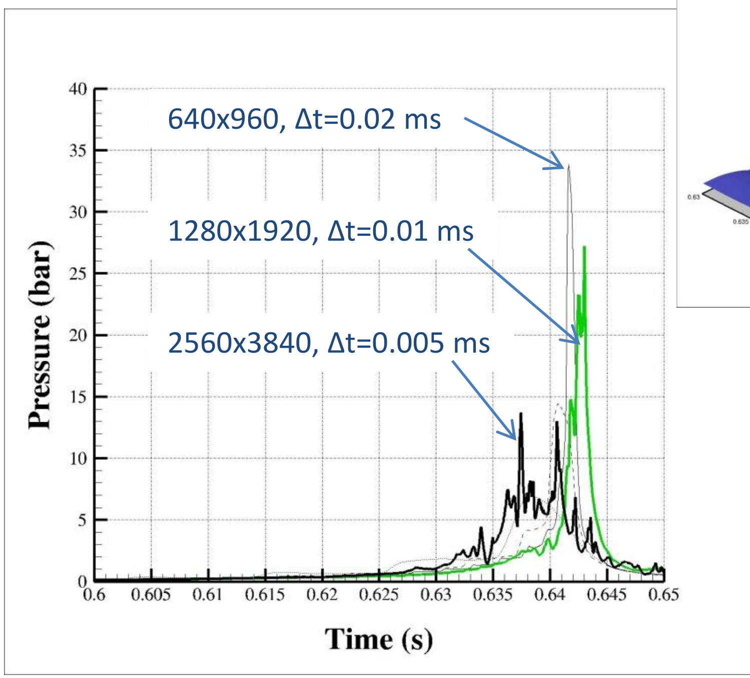
Cartesian

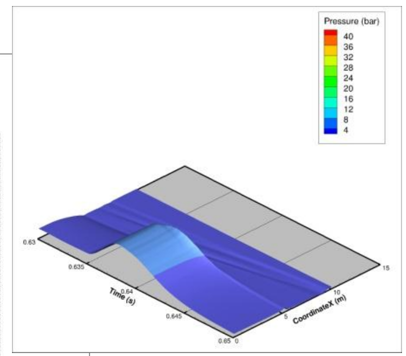


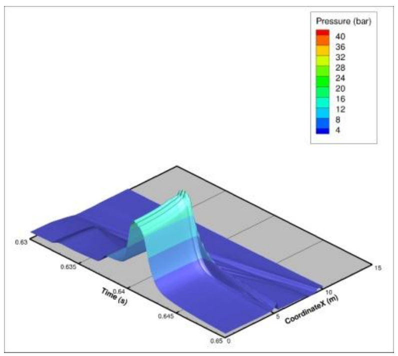
Multi-block structured

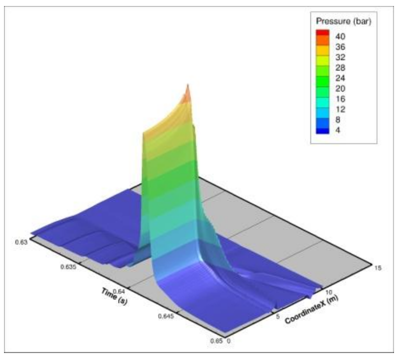
EXTENDED GRID STUDY

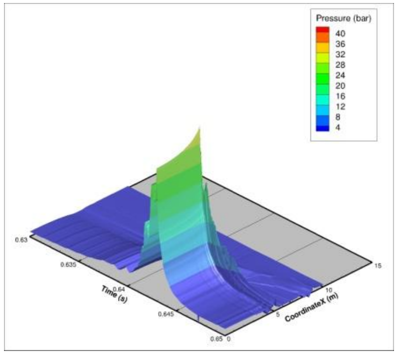
- pressure in P1 and on plate, Cartesian mesh
  - Switch to multiple pressure peaks

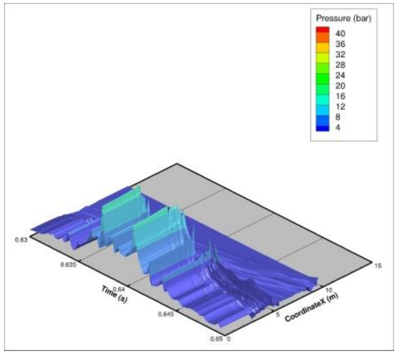






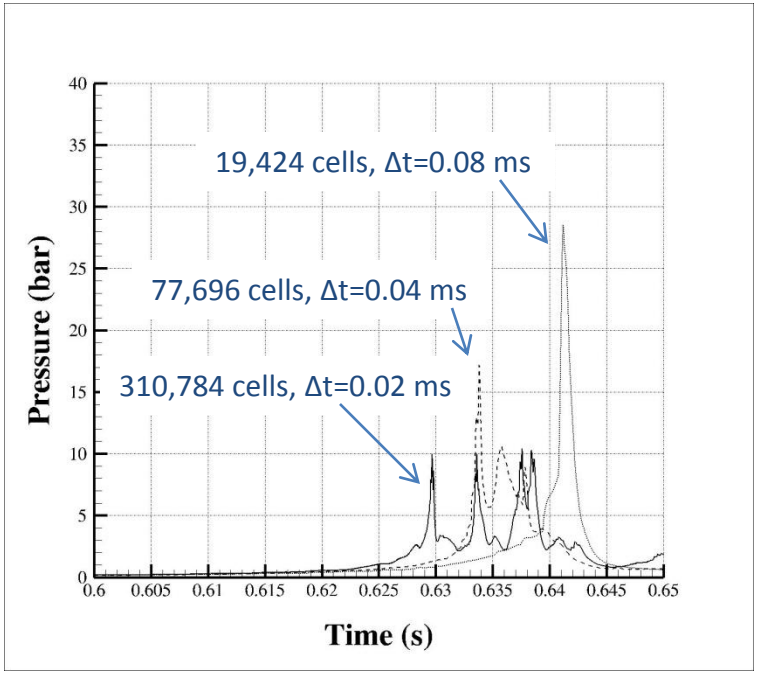


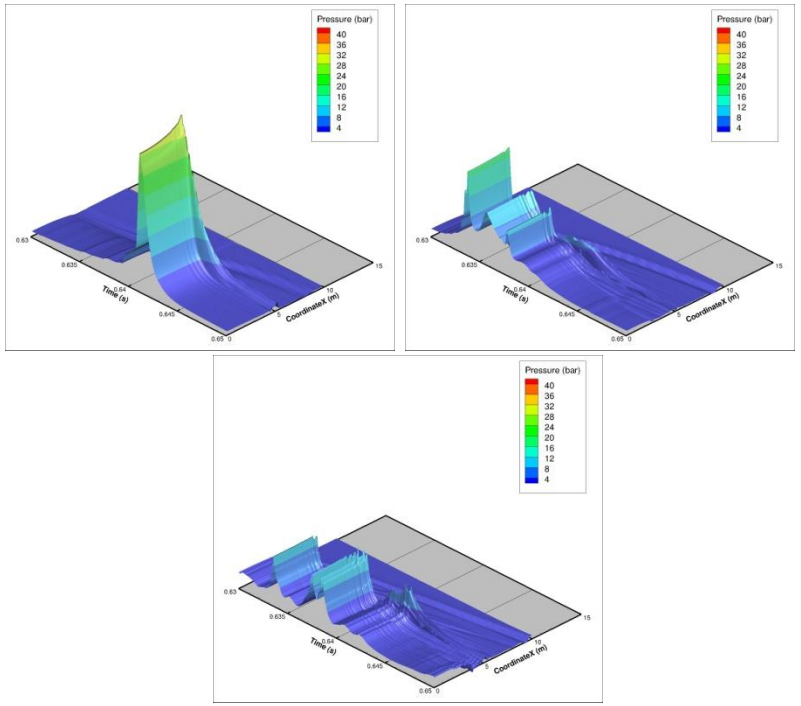




EXTENDED GRID STUDY

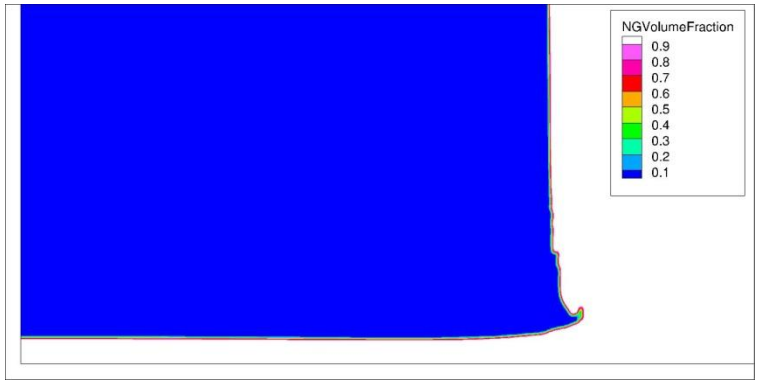
- pressure in P1 and on plate, multi-block structured mesh
  - Same trend: switch to multiple pressure peaks



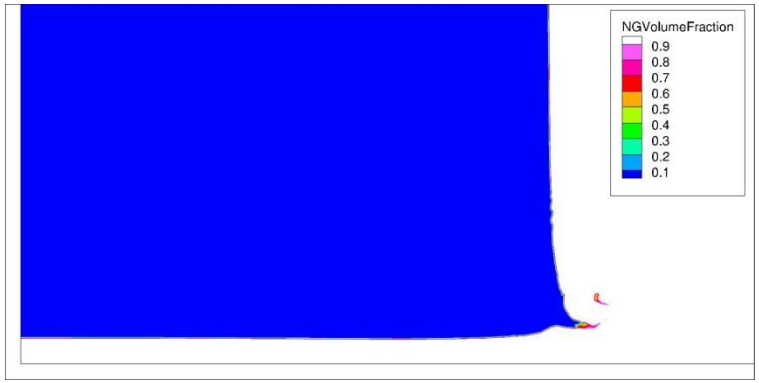


EXTENDED GRID STUDY

- NG volume fraction at t=0.61 s, Cartesian mesh
  - Growing of surface instabilities



640x960

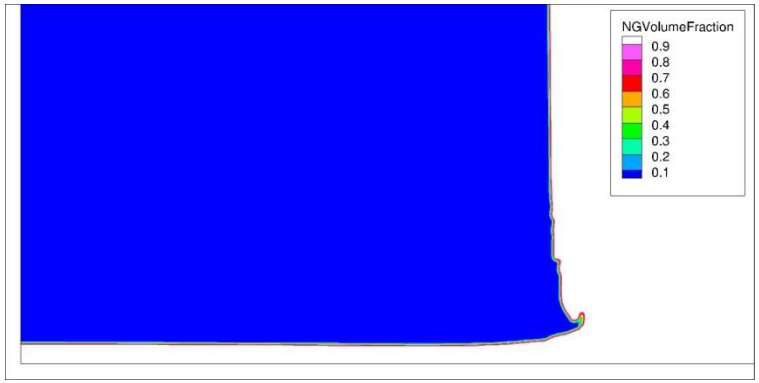


1280x1920

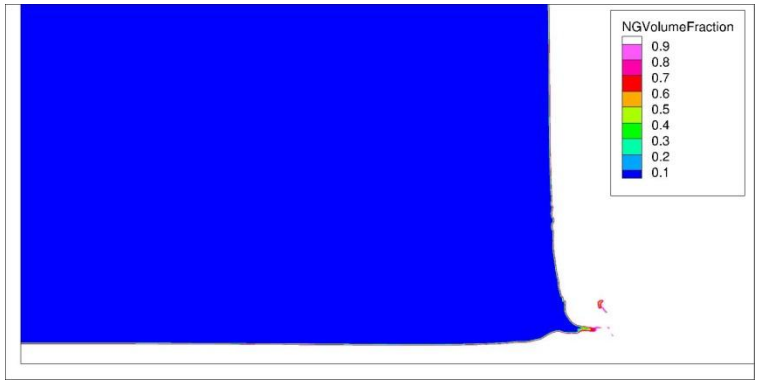
2560x3840

EXTENDED GRID STUDY

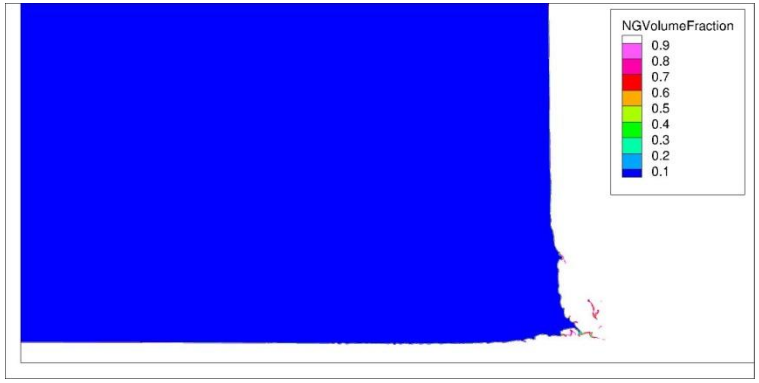
- NG volume fraction at t=0.62 s, Cartesian mesh
  - Growing of surface instabilities



640x960



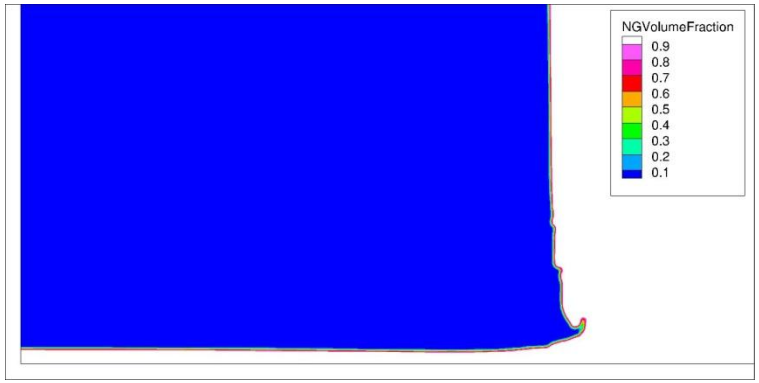
1280x1920



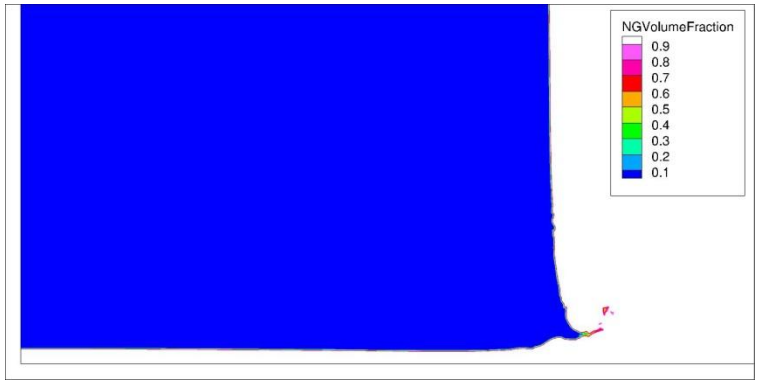
2560x3840

EXTENDED GRID STUDY

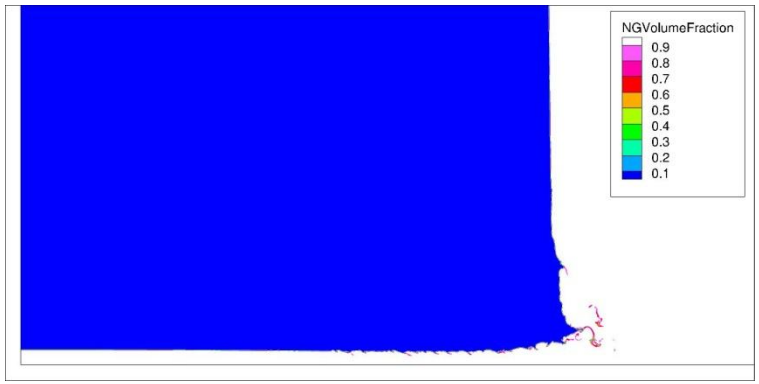
- NG volume fraction at t=0.63 s, Cartesian mesh
  - Growing of surface instabilities



640x960



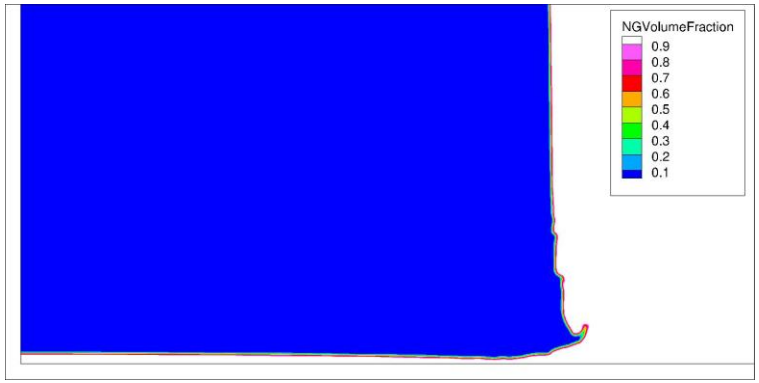
1280x1920



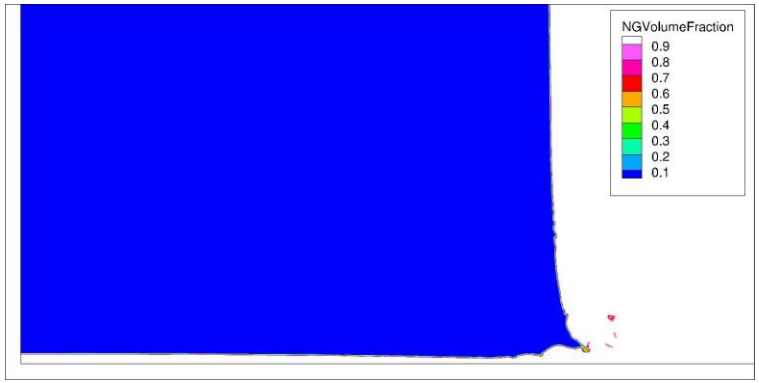
2560x3840

EXTENDED GRID STUDY

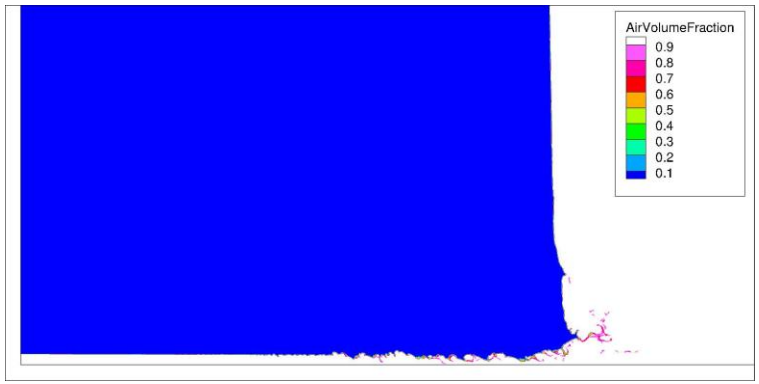
- NG volume fraction at t=0.64 s, Cartesian mesh
  - Growing of surface instabilities



640x960



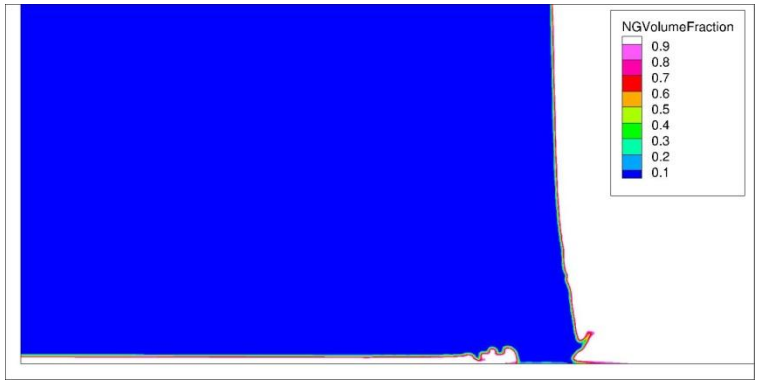
1280x1920



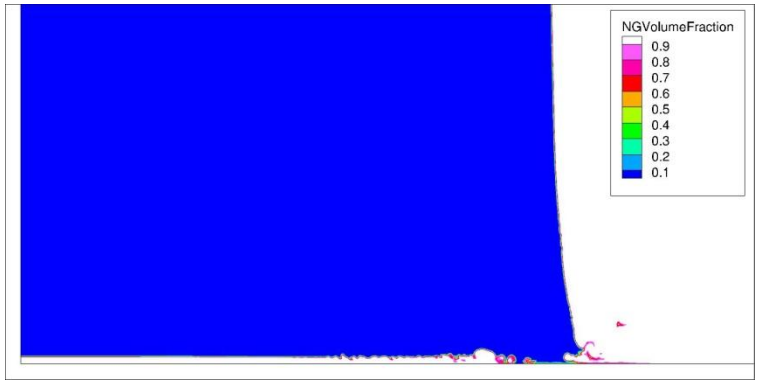
2560x3840

EXTENDED GRID STUDY

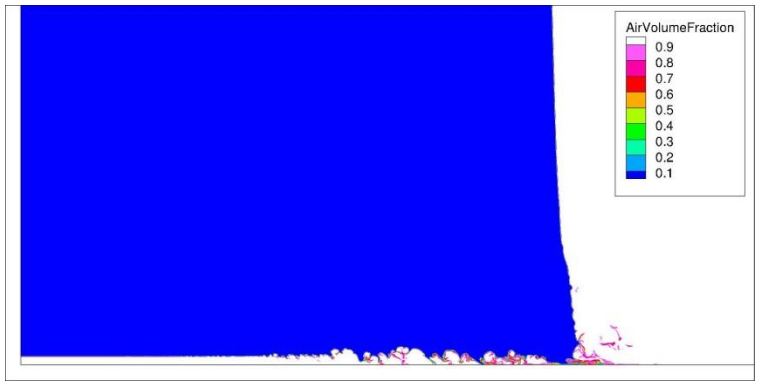
- NG volume fraction at t=0.65 s, Cartesian mesh
  - Growing of surface instabilities



640x960



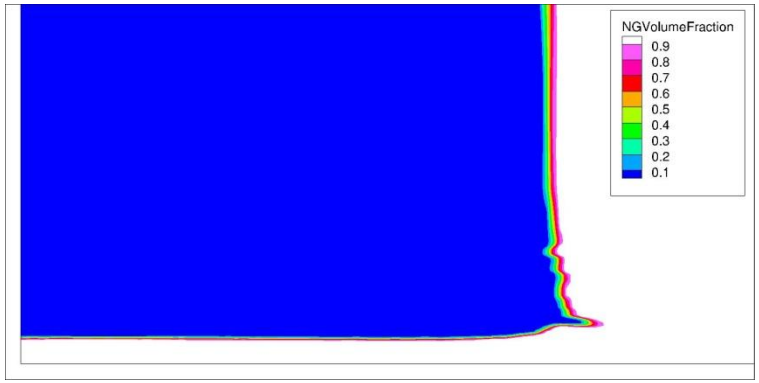
1280x1920



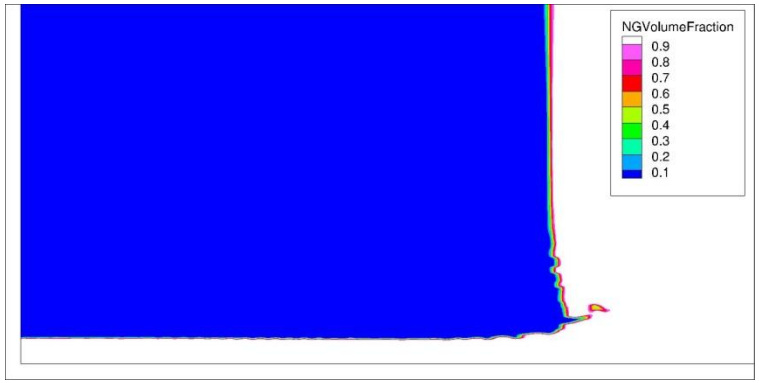
2560x3840

EXTENDED GRID STUDY

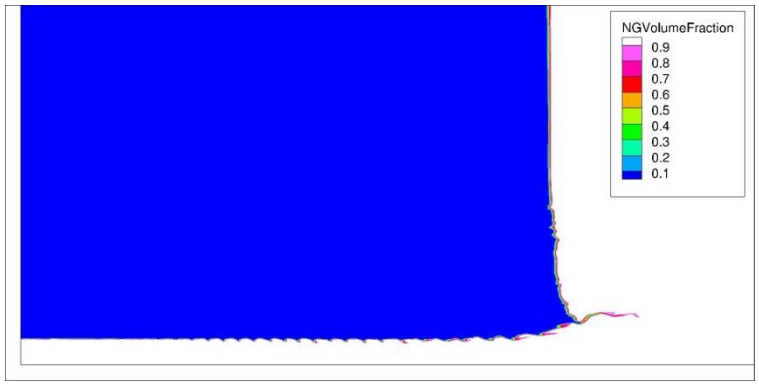
- NG volume fraction at t=0.61 s, multi-block structured mesh
  - Growing of surface instabilities



19,424 cells



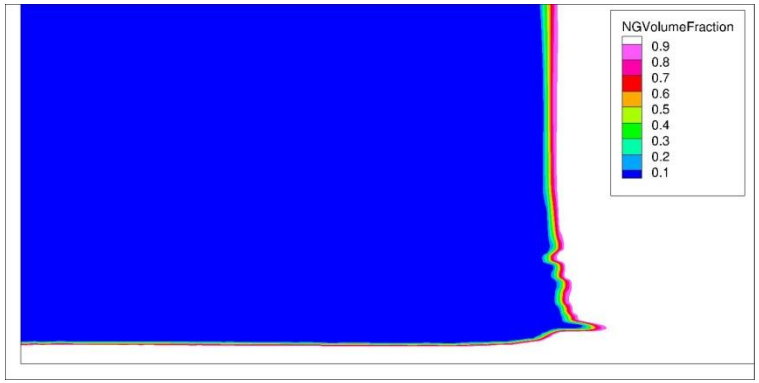
77,696 cells



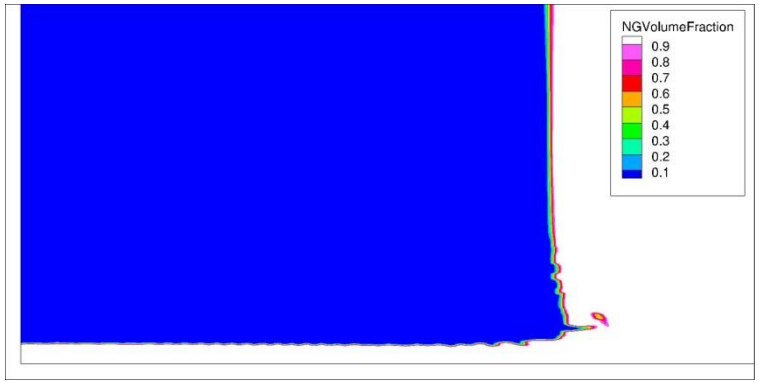
310,784 cells

EXTENDED GRID STUDY

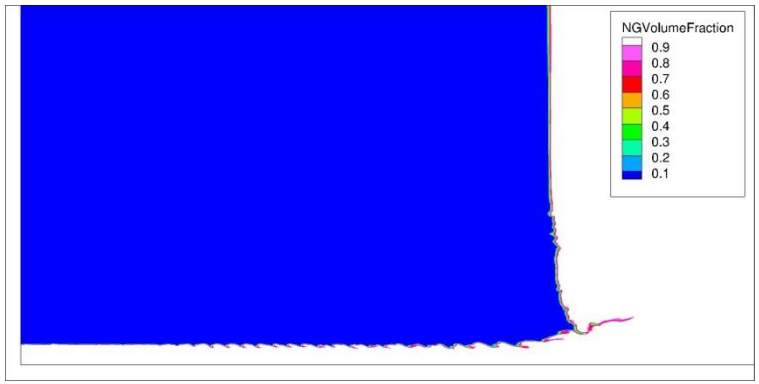
- NG volume fraction at t=0.62 s, multi-block structured mesh
  - Growing of surface instabilities



19,424 cells



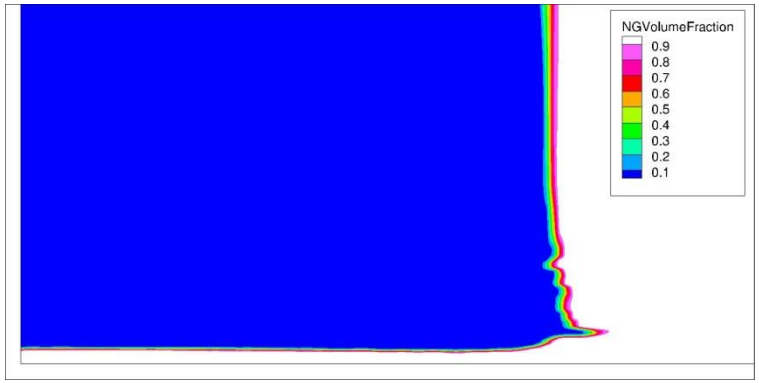
77,696 cells



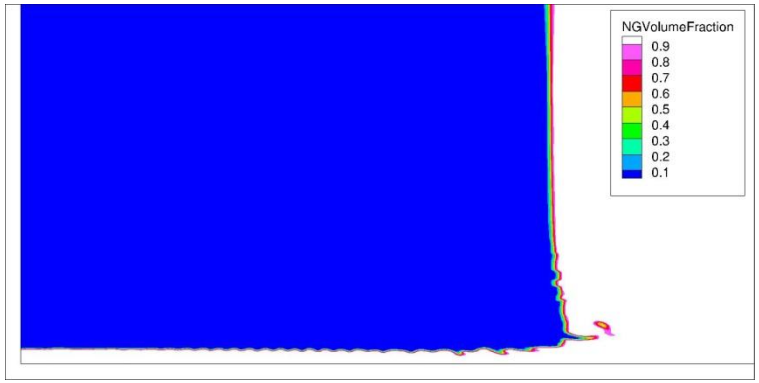
310,784 cells

EXTENDED GRID STUDY

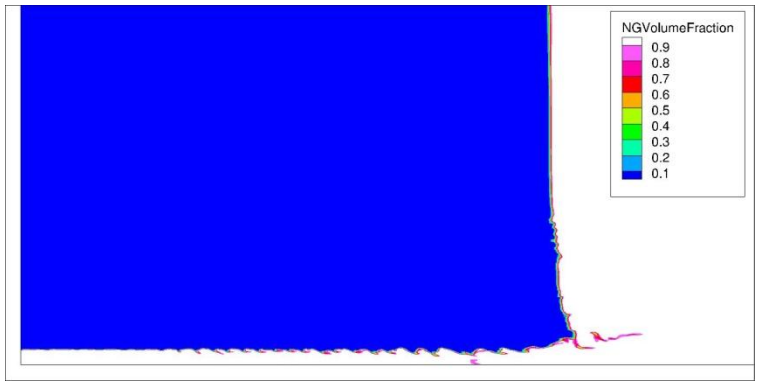
- NG volume fraction at t=0.63 s, multi-block structured mesh
  - Growing of surface instabilities



19,424 cells



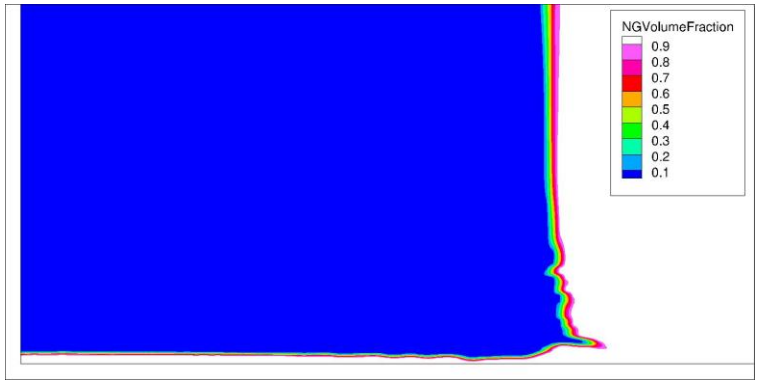
77,696 cells



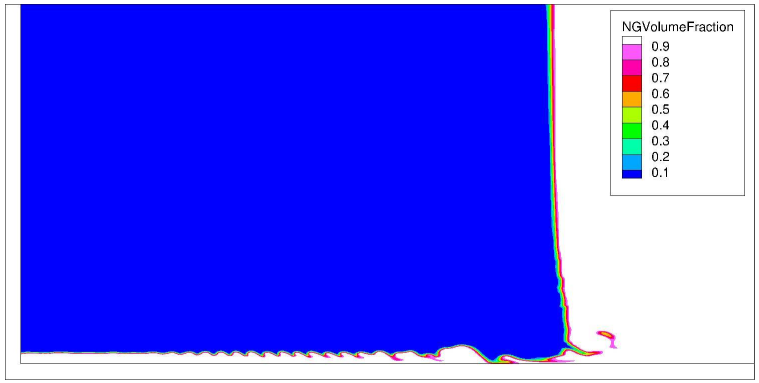
310,784 cells

EXTENDED GRID STUDY

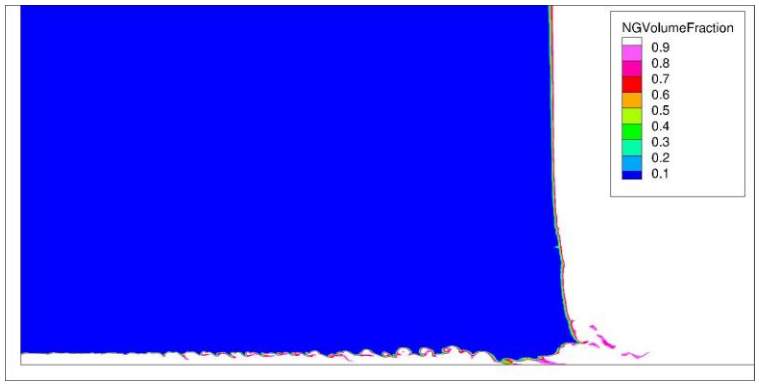
- NG volume fraction at t=0.64 s, multi-block structured mesh
  - Growing of surface instabilities



19,424 cells



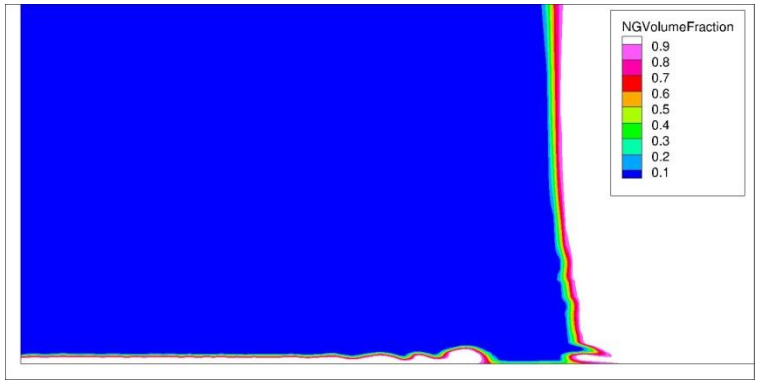
77,696 cells



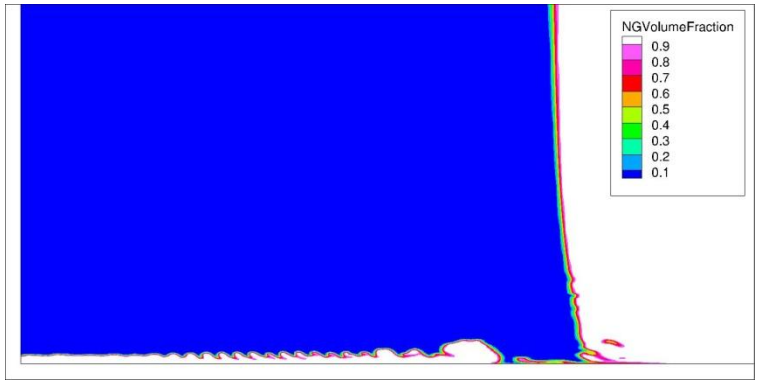
310,784 cells

EXTENDED GRID STUDY

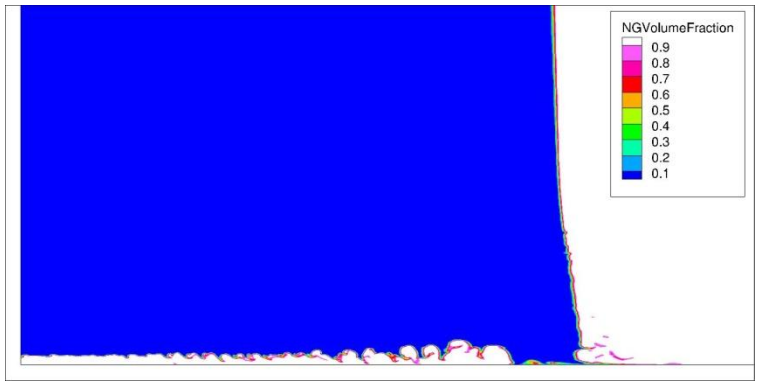
- NG volume fraction at t=0.65 s, multi-block structured mesh
  - Growing of surface instabilities



19,424 cells



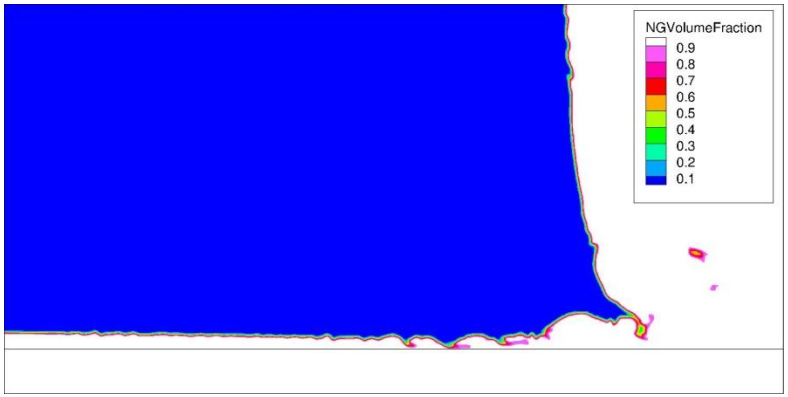
77,696 cells



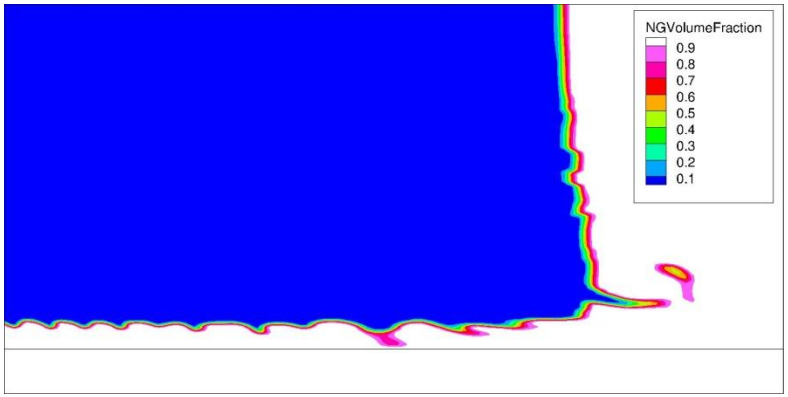
310,784 cells

EXTENDED GRID STUDY

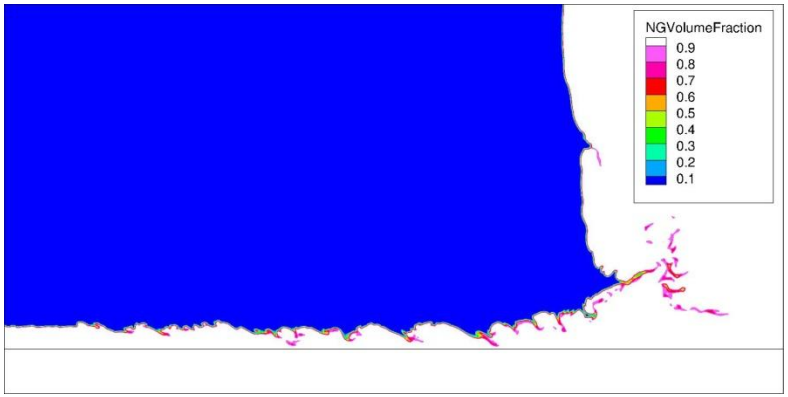
- Patch shape at first pressure peak



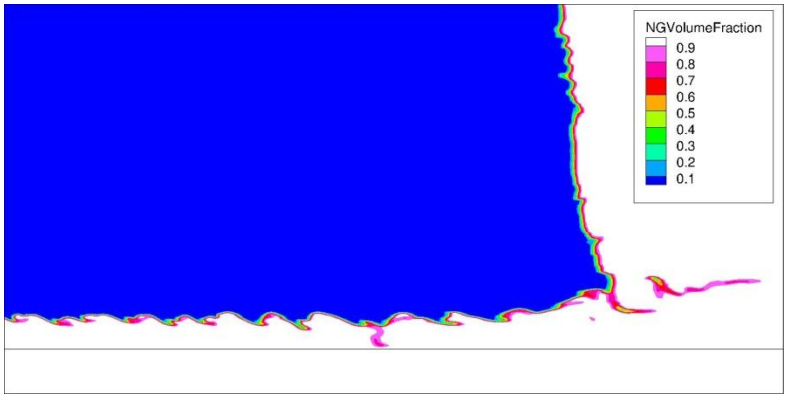
1280x1920



77,696 cells



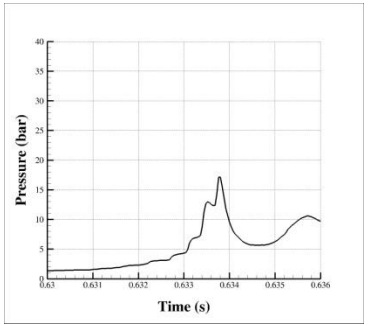
2560x3840

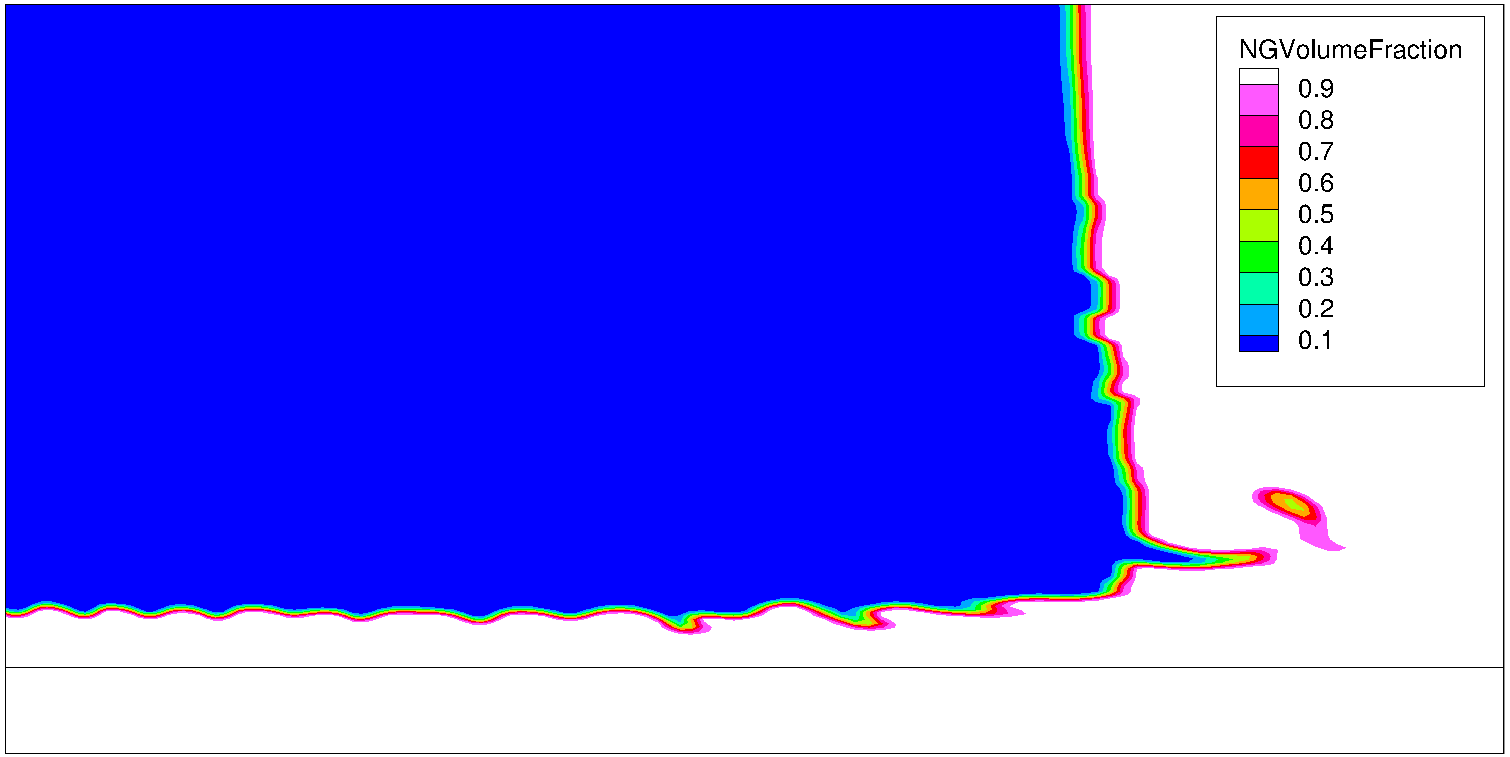


310,784 cells

EXTENDED GRID STUDY

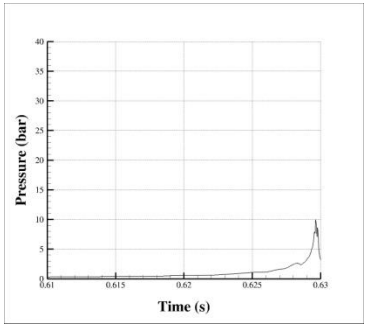
- 77,696 cells, t=0.63 s – 0.636 s





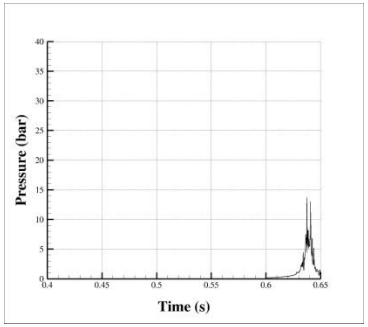
EXTENDED GRID STUDY

- 310,784 cells, t=0.61 s – 0.63 s



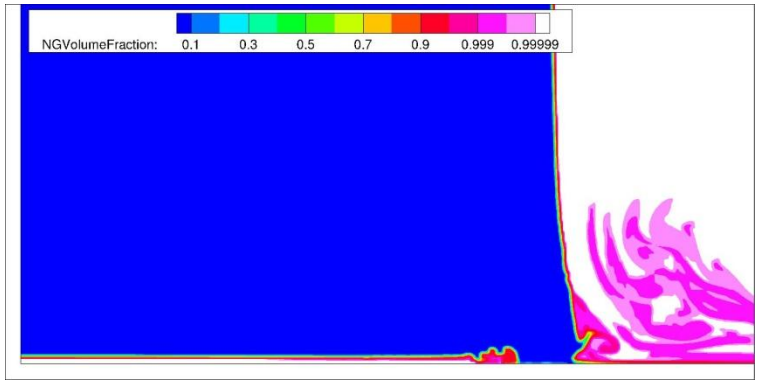
EXTENDED GRID STUDY

- 2560x3840 cells, t=0.4 s – 0.65 s

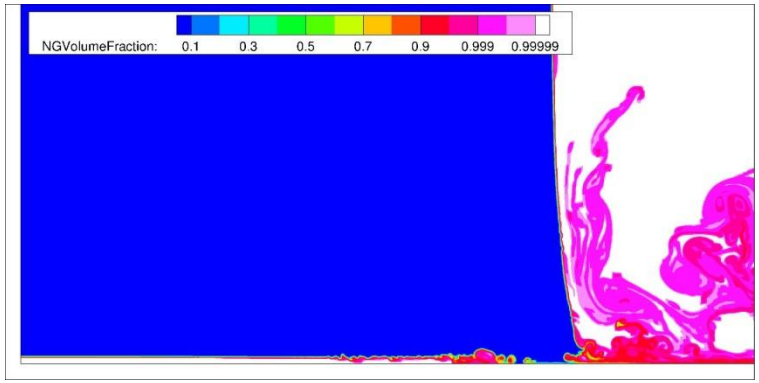


EXTENDED GRID STUDY

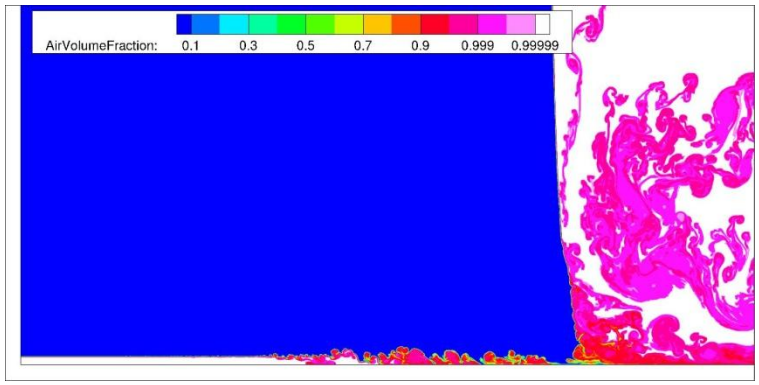
- NG volume fraction at t=0.65 s, Cartesian mesh
  - Sharpness of the interface



640x960



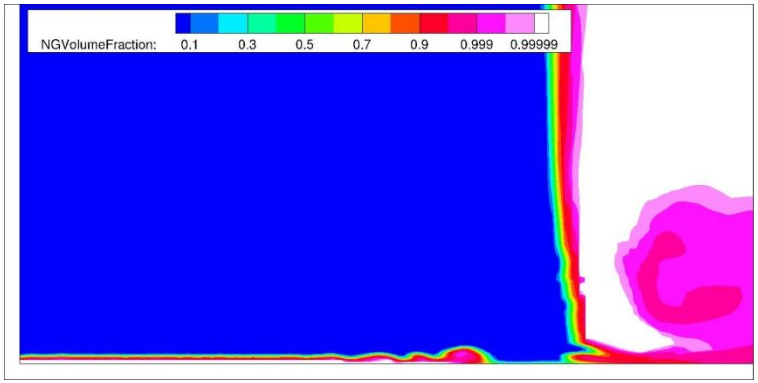
1280x1920



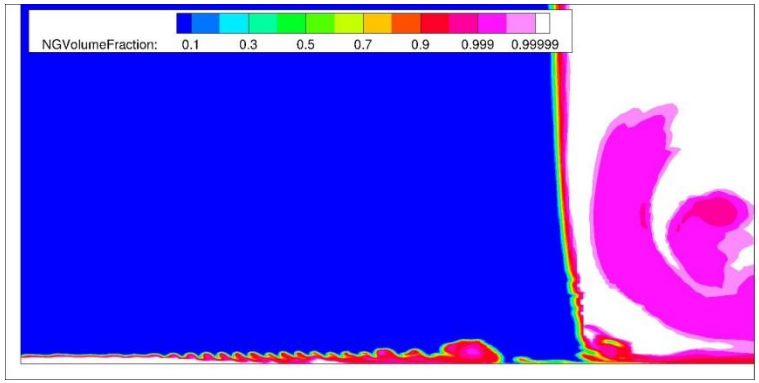
2560x3840

EXTENDED GRID STUDY

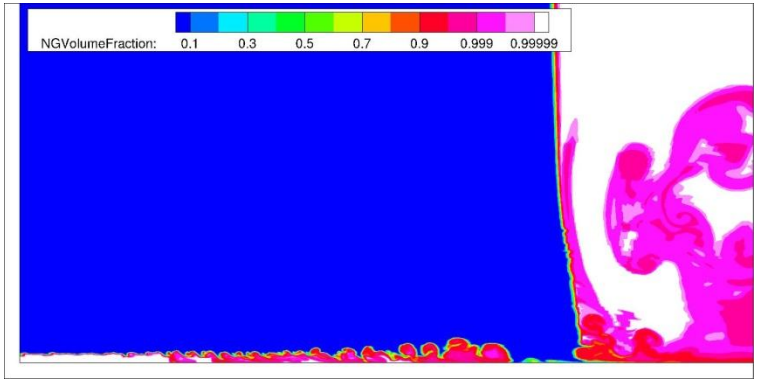
- NG volume fraction at t=0.65 s, multi-block structured mesh
  - Sharpness of the interface



19,424 cells



77,696 cells



310,784 cells

CONCLUSION & FUTURE WORK

- Conclusions
  - VOF method with a good interface capturing scheme gives fairly good results?
  - The solution is still grid-dependent!
  - Multi-block meshes give comparable results, but much more efficient

- Future work
  - Apply adaptive mesh refinement
  - Interface reconstruction
  - Surface tension
  - Compressibility