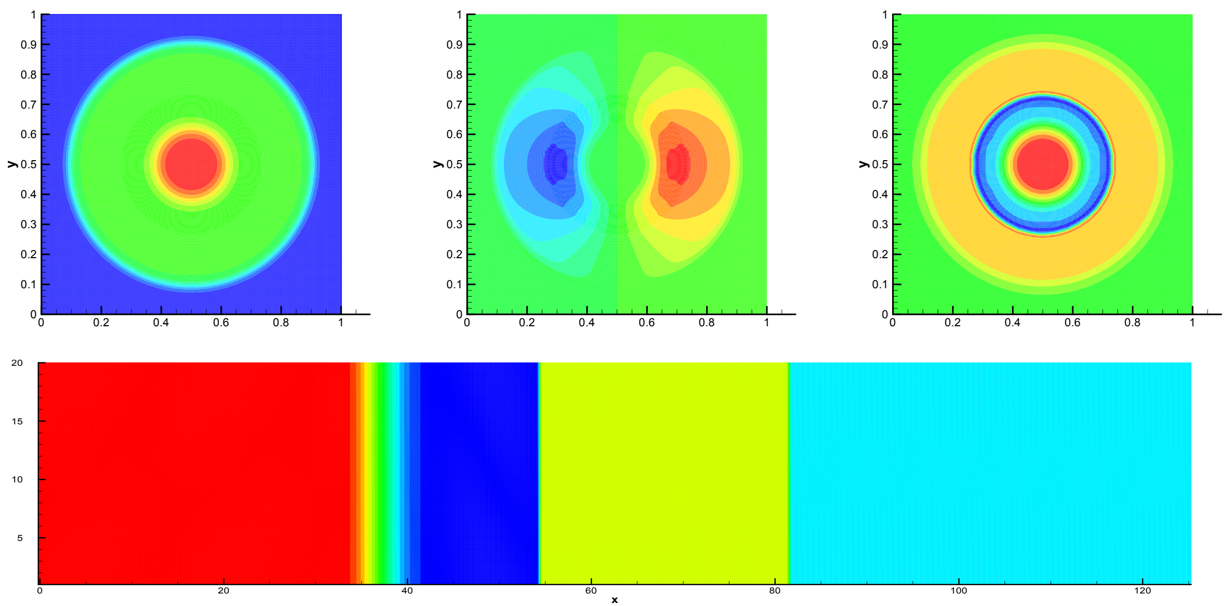
SPHERIC

# Multiphase Godunov-typed SPH Method with Approximate Riemann Solvers

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# Contents

1. Multiphase Riemann problems
2. Multiphase Godunov-typed SPH (MGSPH) method
3. Numerical results
4. Conclusions

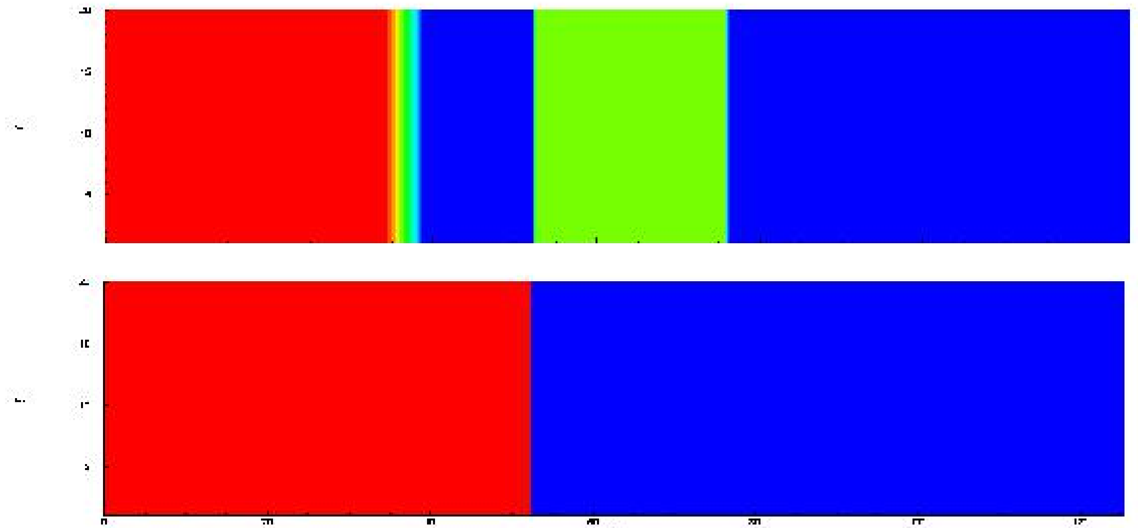
# 1. Multiphase Riemann problems

## ◆ Multiphase Riemann problems

- multiphase flow in an Eulerian framework with discontinuous initial conditions
- shock tube problems, underwater explosion problems and so on

## ◆ Difficulties

- Interface tracking
- Discontinuous initial conditions
- Different Equations of State (EOSs)



# 2. Multiphase Godunov-typed SPH

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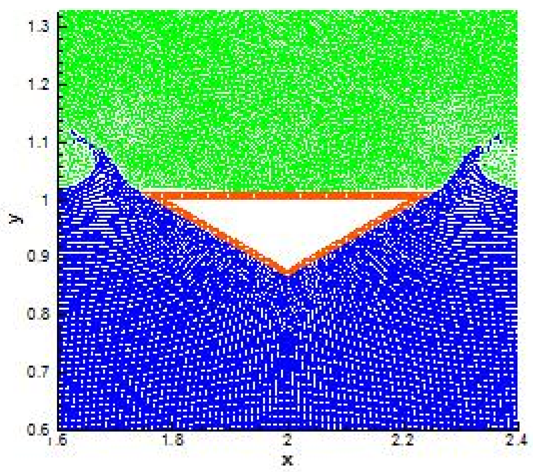
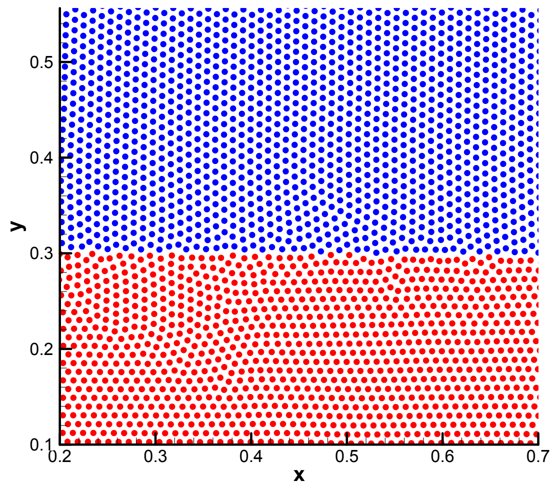
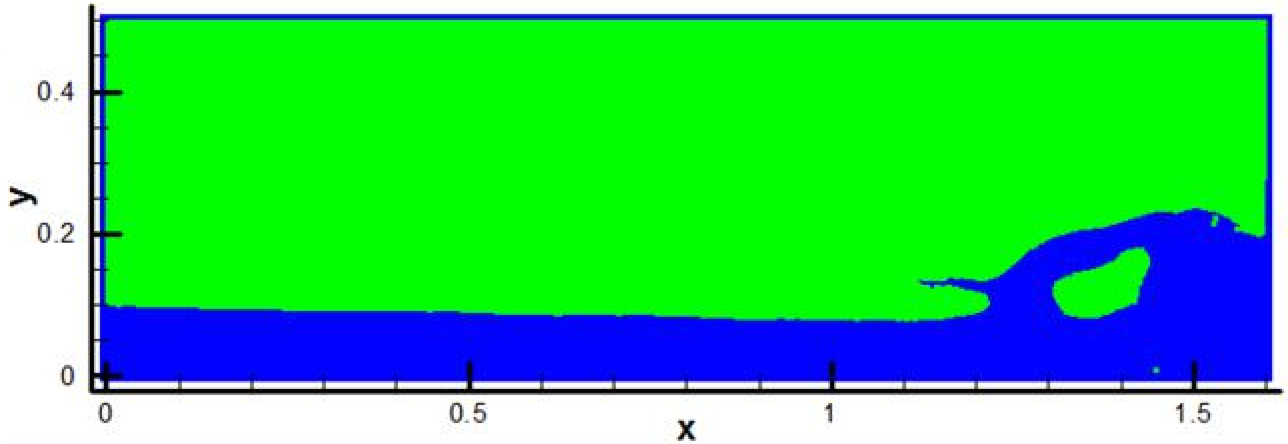
◆ SPH: interface tracking



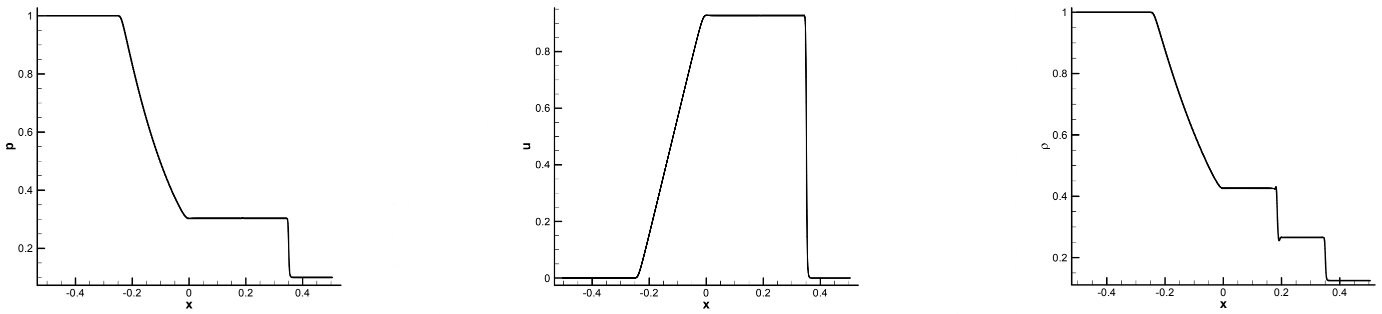
# 2. Multiphase Godunov-typed SPH

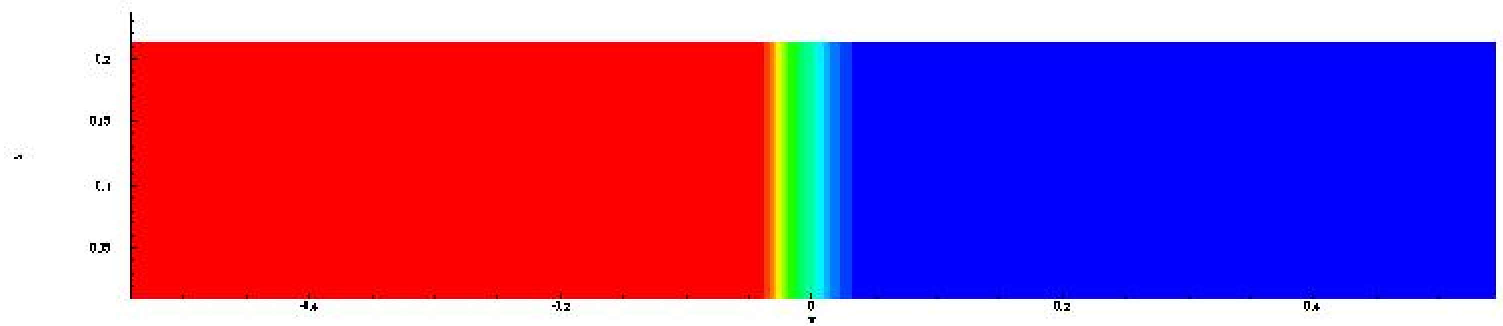
◆ GSPH: discontinuous initial conditions

$$\rho_a = \sum_b m_b W_{ab}$$

$$\frac{dv_a}{dt} = -2\sum_b m_b \frac{P^*}{\rho_a \rho_b} \nabla_a W_{ab}$$

$$\frac{dE_a}{dt} = 2\sum_b m_b \frac{P^* u^*}{\rho_a \rho_b} \cdot \boldsymbol{e}_{ab} \cdot \nabla_a W_{ab}$$

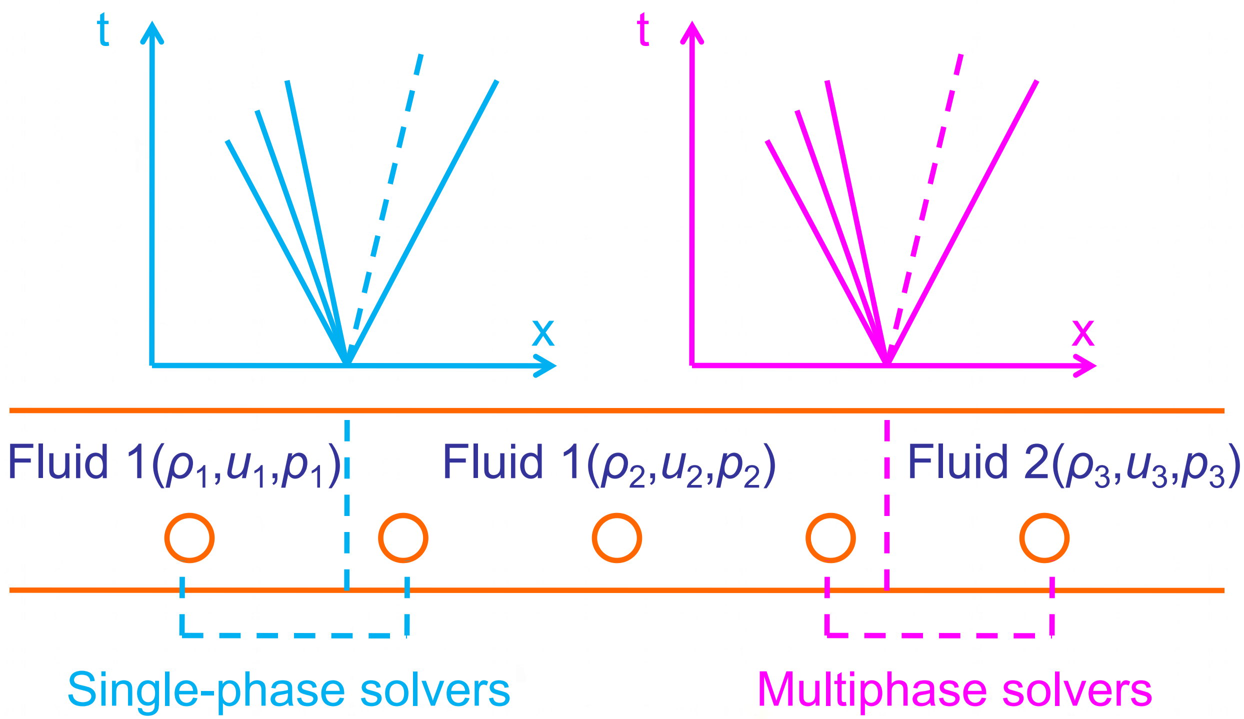


# 2. Multiphase Godunov-typed SPH

## ◆ MGSPH: different Equations of State

- single-phase approximate Riemann solver is implemented in the inner area
- multiphase approximate Riemann solver is adopted to the interface



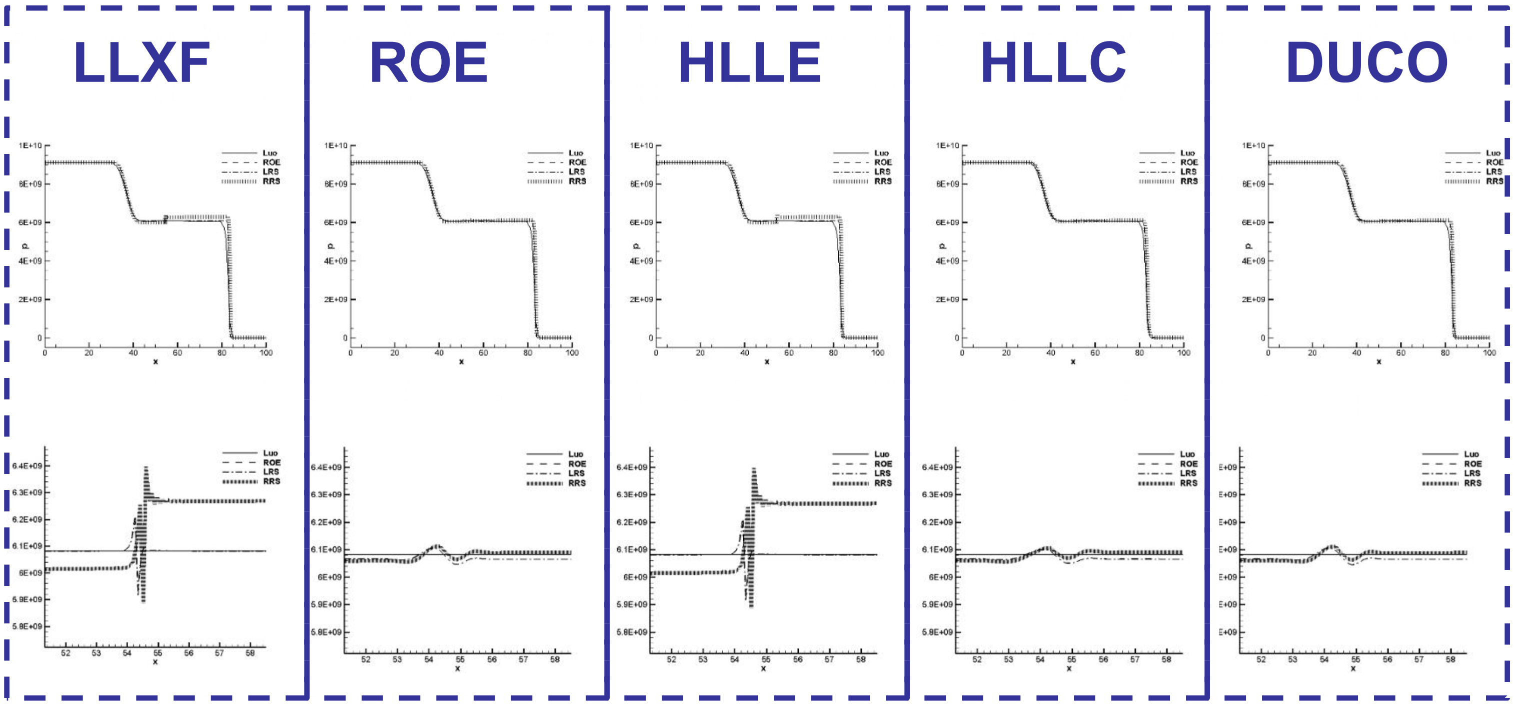
# 3. Numerical results

- **Single-phase approximate Riemann solvers**
  - The local Lax–Friedrichs Riemann solver(LLXF)
  - Roe's approximate Riemann solver(ROE)
  - Harten, Lax, van Leer and Einfeldt approximate Riemann solver (HLLE)
  - Harten, Lax and van Leer scheme with contact (HLLC)
  - Ducowicz approximate Riemann solver (DUCO)
- **Multiphase approximate Riemann solvers**
  - Linearized wave curves (LRS) by Fechter and Schleper
  - Relaxation approach (RRS) by Fechter and Schleper
  - Roe's approximate Riemann solver (ROE)
- **15 combinations**

# 3. Numerical results

## Gas-water shock tube

| Fluid | $(\rho,u,P)$ | EOS | Parameters in EOS |
|---|---|---|---|
| Left | (1.271, 0, 9.119252E9) | $P=(\gamma-1)\rho e-\gamma P_c$ | $\gamma=1.4$; $P_c=0$ |
| Right | (0.999983, 0, 1.01325E6) | $P=(\gamma-1)\rho e-\gamma P_c$ | $\gamma=7$; $P_c=3.03975E9$ |

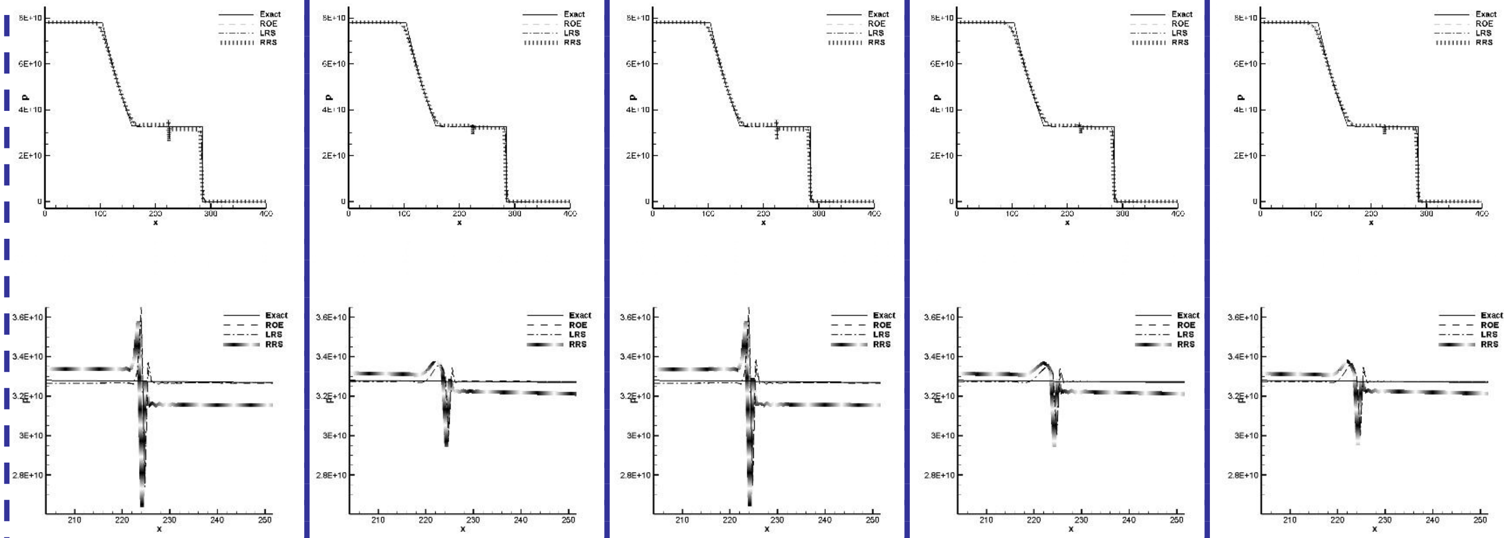


# 3. Numerical results

## ◆ Underwater explosion

| Fluid | $(\rho,u,P)$ | EOS |
|---|---|---|
| Left | (1.63, 0, 7.81E10) | Tait's EOS |
| Right | (1, 0, 1E6) | JWL equation |

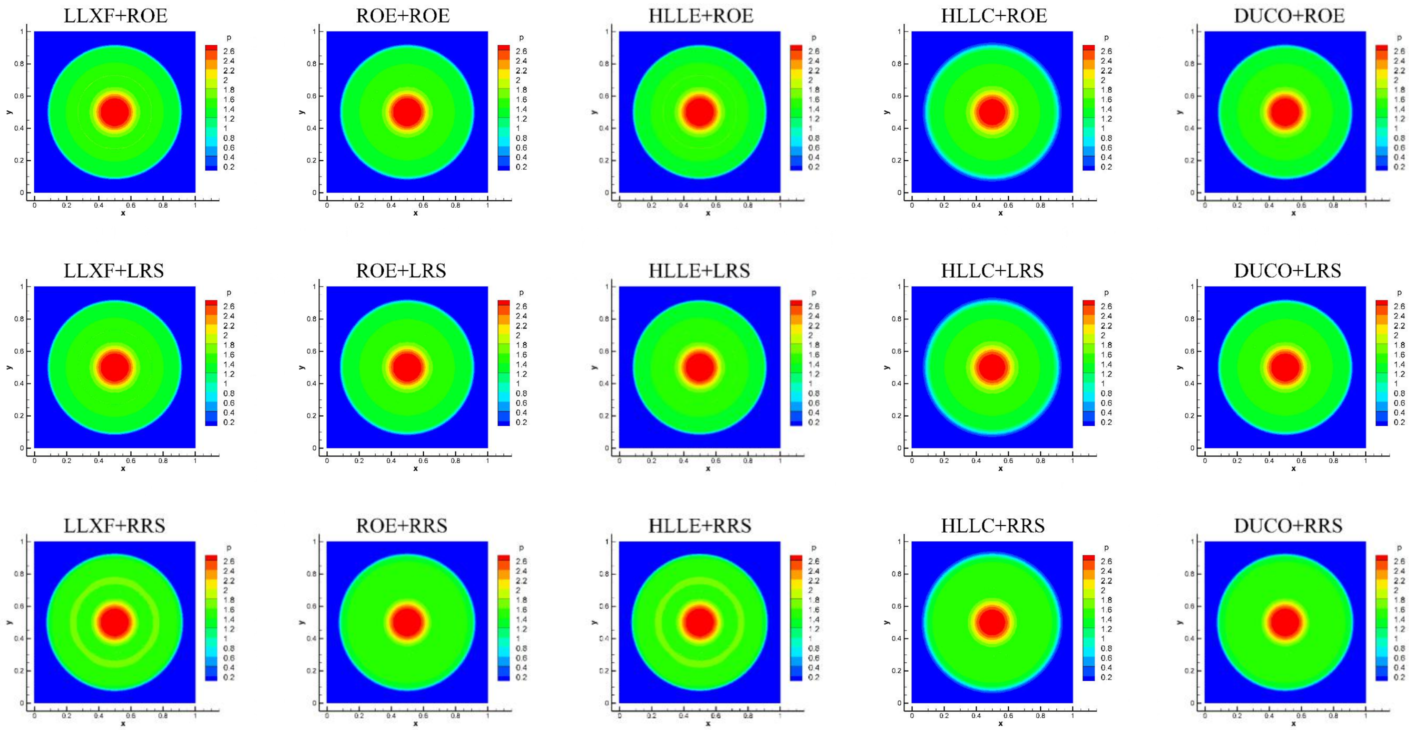
**LLXF** **ROE** **HLLE** **HLLC** **DUCO**



# 3. Numerical results

## ◆ 2D radially symmetric problem

| Fluid | $(\rho,u,v,P)$ | EOS | Parameters in EOS |
|---|---|---|---|
| Bubble | (1.241, 0, 0, 2.753) | $P=(\gamma-1)\rho e-\gamma P_c$ | $\gamma=1.4$; $P_c=0$ |
| Water | (0.991, 0, 0, 3.059E-4) | $P=(\gamma-1)\rho e-\gamma P_c$ | $\gamma=5.5$; $P_c=1.505$ |



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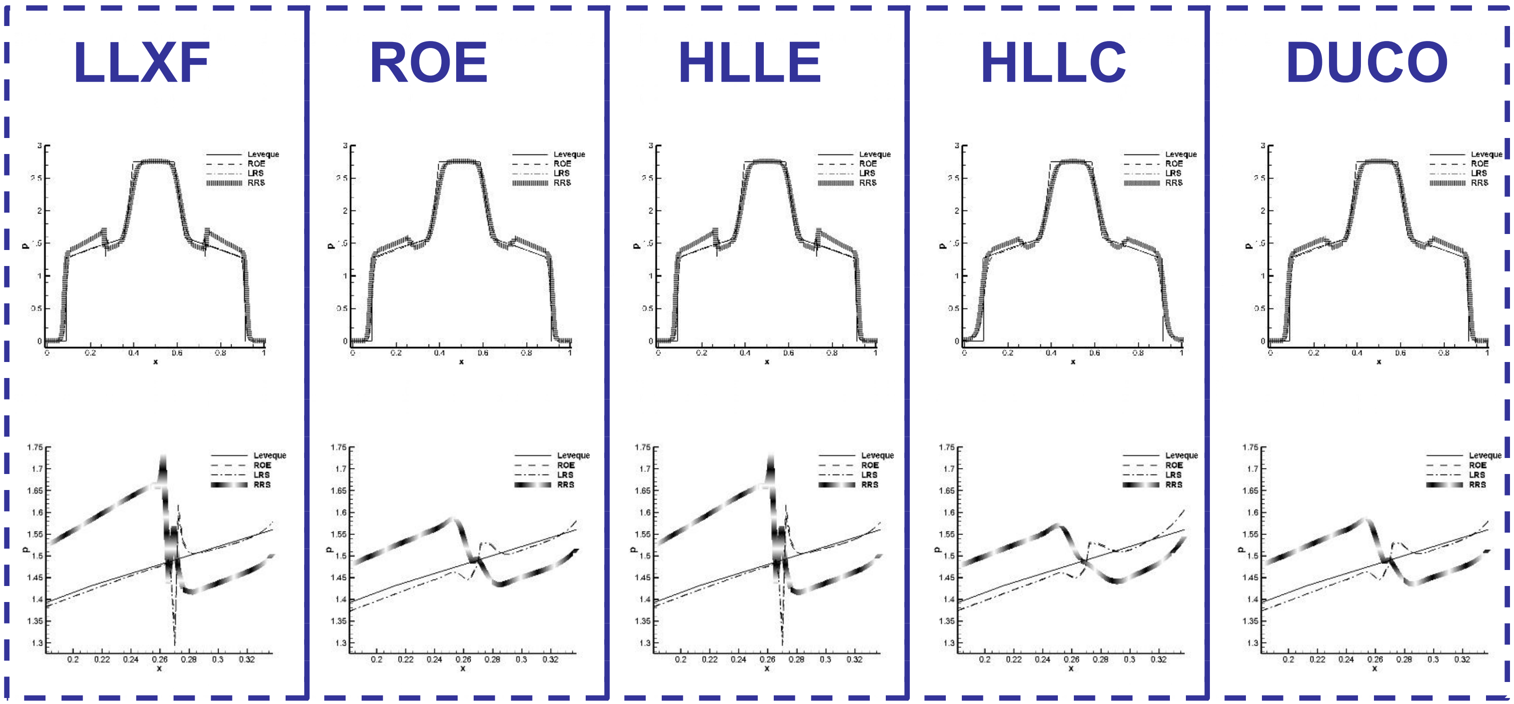
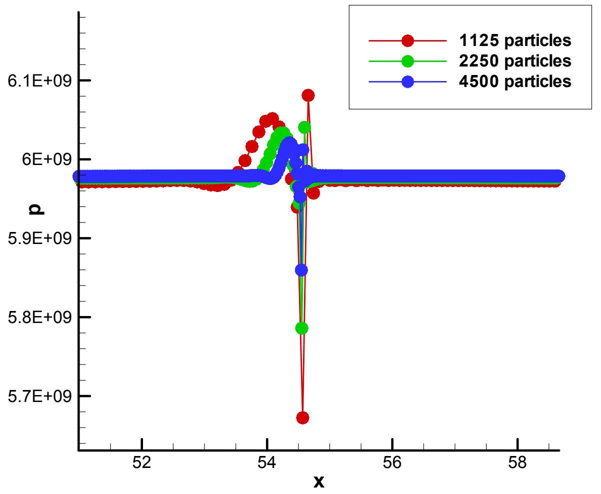
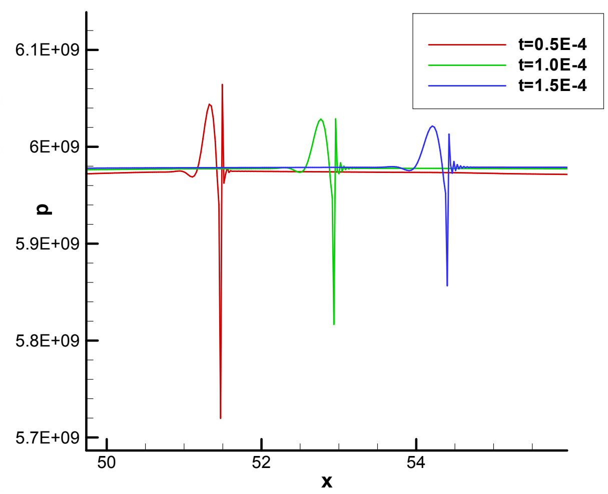
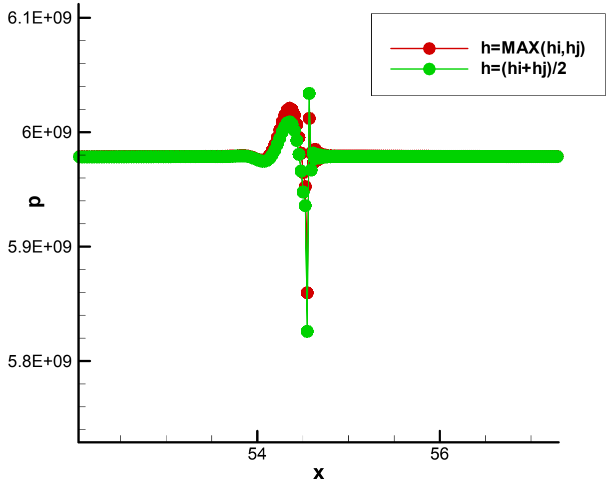


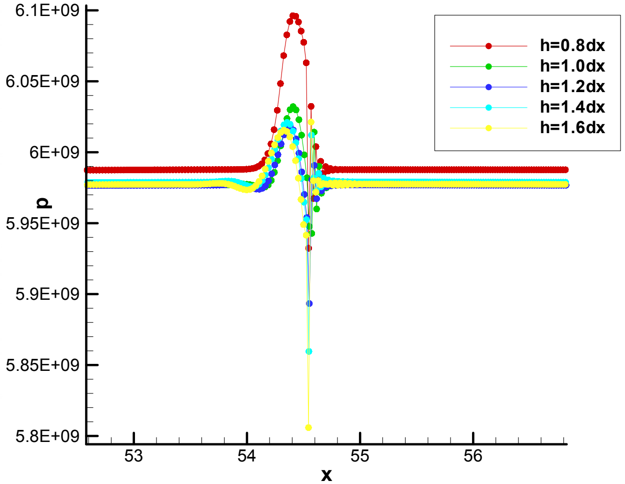
# 3. Numerical results

## Broken features



# 4. Conclusion

## ◆ MGSPH

- MGSPH combined with Godunov-typed SPH model(GSPH), single-phase approximate Riemann solvers and interfacial approximate Riemann solvers is developed for multiphase Riemann problems with multiple Equations of States (EOSs).
- Discontinuous presures  is found in the solutions obtained by RRS, which is due to the error introduced by using the relaxed pressure.
- Broken features occur in pressure distribution curves due to the contact discontinuity.

# 4. Conclusions

## ◆ Broken features

- Broken features are sensitive to the approximate Riemann solver, initial particle distance, simulation time and smooth length.
- The broken features of cases with LLXF and HLLE are more severe than other single-phase solvers.
- Smaller initial particle distances lead to less severe broken features.
- Broken features are erased as simulation time goes by.
- The method for computation of smooth length has affection on broken features.
- Smallest broken features occur when h=dx(fifth-order quintic spline kernel function).

**Thank you**
**for your attention !**