Volume of Fluid (VOF) In PHOENICS

CHAM

Experts in CFD Software and Consultancy

Introduction

PHOENICS was the *first* commercial Computational Fluid Dynamics (CFD) Software made available, in 1981, to a world market currently valued at over £2.5 billion sterling. PHOENICS was based on a lifetime of the scientific knowledge of Professor Brian Spalding, FRS, FREng, the founding father of CFD. His team at CHAM work with the code to ensure that it remains not only the most established CFD software, but also easy to use. Updates include features requested by Users and Agents, those suggested by advances in technology and those related to current environmental and industrial issues.

Volume Of Fluid (VOF)

The PHOENICS Volume-Of-Fluid (VOF) capability has improved the accuracy of interface resolution for immiscible-fluid and free-surface flows including surface-tension effects at the interface of two fluids modelled using the continuum-surface-force (CSF) model proposed by Brackbill et al (1992).

VOF tracks free surface or fluid-fluid interfaces by solving a volume-fraction equation on a fixed Eulerian mesh with a single set of momentum equations shared by two fluids. The volume-fraction equation distinguishes between the two fluids, but the convection terms need special treatment to address numerical smearing of the interface over several mesh cells, whilst ensuring boundedness of computed volume fractions. Techniques classified as geometric-interface-reconstruction methods, donor-acceptor schemes or higher-order discretization schemes maintain a well-defined interface.

The last technique is used in PHOENICS with high-resolution methods implemented as options: CICSAM (Compressive Interface Capturing Scheme for Arbitrary Meshes), HRIC (High Resolution Interface Capturing scheme), modified HRIC and STACS (Switching Technique for Advection and Capturing of Surfaces). The schemes are superior interface capturing to the existing Scalar-Equation-Method (SEM).

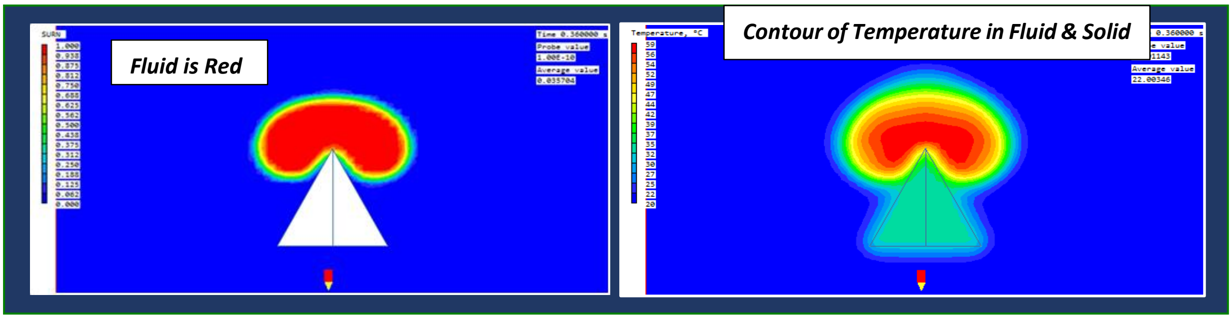
PHOENICS offers all Free-Surface / Volume of Fluid Models available in other CFD codes including:

- VOF-CICSAM (Compressive Interface Capturing Scheme for Arbitrary Meshes)
- VOF-HRIC (High Resolution Interface Capturing Scheme)
- VOF-MHRIC (Modified HRIC)
- VOF-STACS (Switching Technique for Advection and Capturing of Surfaces)

The models offer a sharper interface than Height of Liquid (HOL) and Scalar Equation (SEM) Methods. All models available can include surface tension force using CSF. Options allow making surface tension a linear function of temperature, or using the Langmuir equation of state which includes a scalar as well as temperature. A constant static contact angle can be specified to model wall adhesion effects.

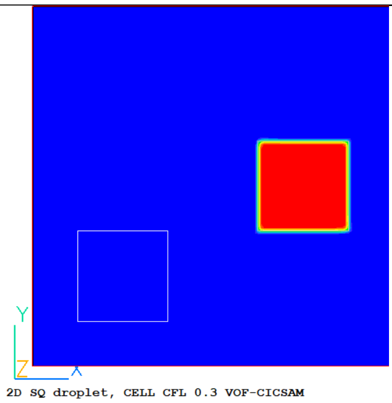
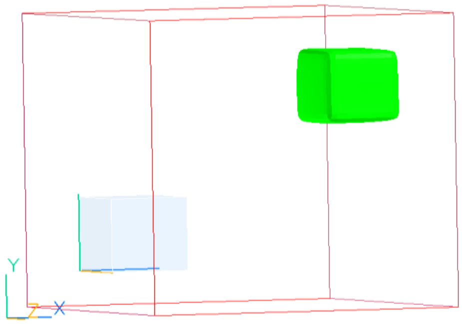
A VOF feature implemented in PHOENICS is THINC-WLIC. THINC (Tangent of Hyperbola for INterface Capturing) uses hyperbolic tangent functions to devise a conservative, oscillation-less, smearing-less scheme with no geometry reconstruction which is competitively accurate compared to most existing methods. Multi-dimensional computing is conducted by WLIC (Weighted Line Interface Calculation).

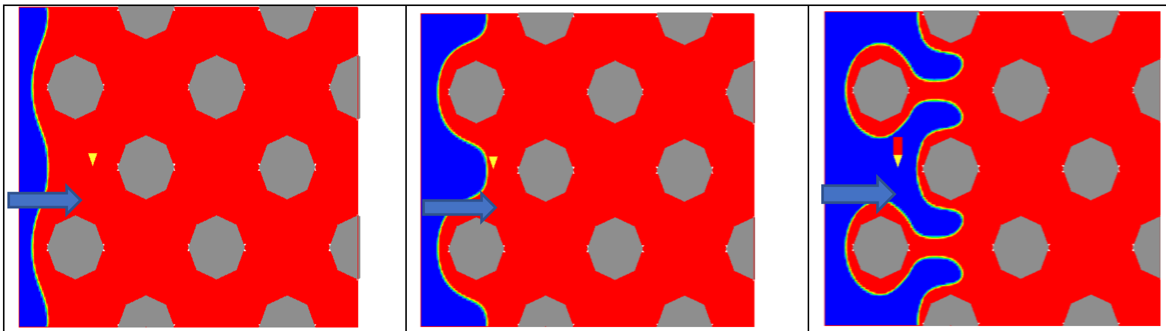
All VOF methods can solve temperature-dependent cases, with proper treatment of temperature in each phase and in immersed solids. The images show a drop of hot fluid falling over a solid obstacle.

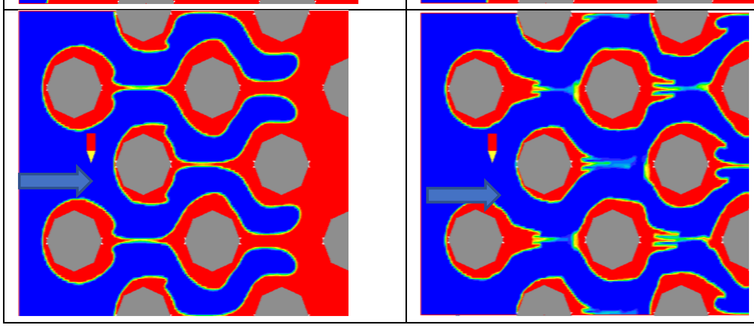


Verification

Examples below demonstrate CICSAM. For animations see www.cham.co.uk or www.facebook.com/arcofluid.

	
Squared water drop in an oblique air flow in 2D after 0.3s. Initial drop at the light square. Using VOF-CICSAM.	***Squared water drop in an oblique air flow in 3D after 0.3s. Initial drop at the light square. Using VOF-CICSAM.***





Near Critical CO2 flowing in a channel with octagonal micropillars filled with water. At different instant in dimensionless time: 0.28, 0.52, 1.04, 2.04.

MHRIC and STACS have proven superior to other methods when the local CFL number is over 0.45. These methods have been tested using the Zalesak disc in a fixed rotating velocity field. This case is a well-known benchmark for free surface numerical methods; one can observe if the shape of the slotted disc is retained during rotation around the red spot

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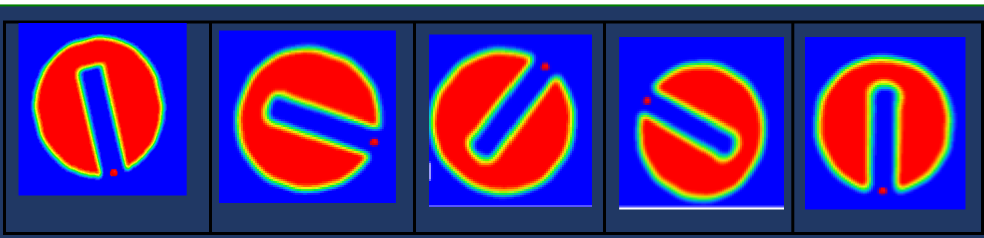
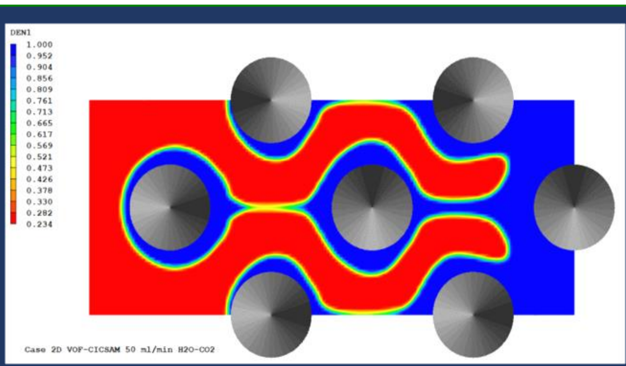
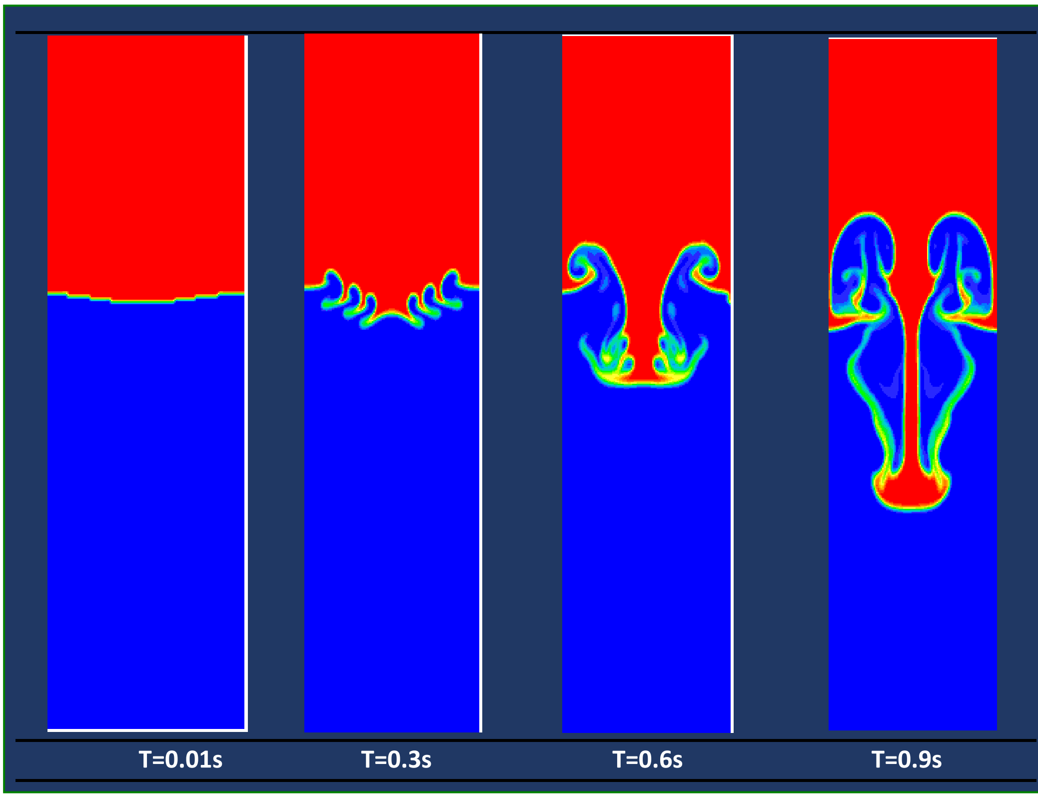
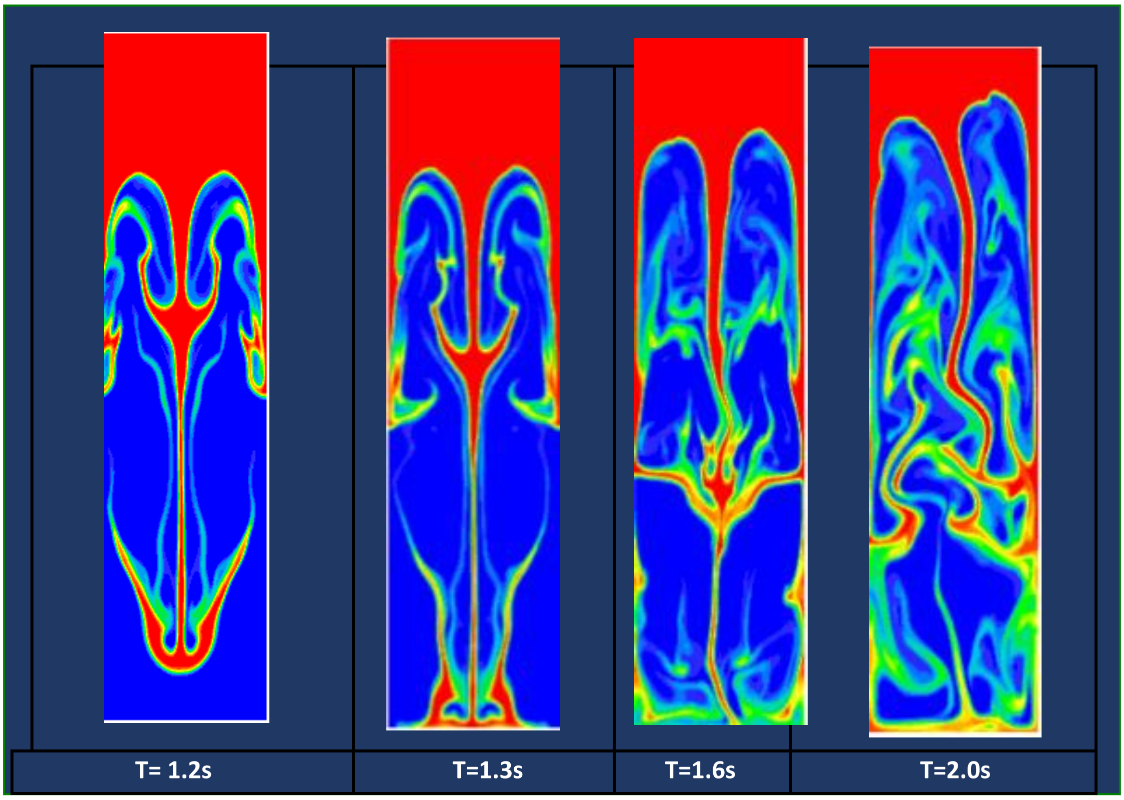


Zalesak Disc Case: Heavy Fluid in red (Water), Light Fluid in blue (Air). Number of cells in X & Y direction: 200 x 200. Timestep: 7.97 10^{-4}. Method used is the STACS algorithm which shows a well-preserved shape of the slotted disc. Disc diameter: 25 cm. Rectangular slot inside disc: 5cm x 20cm



VOF-STACS is applied to a classical Rayleigh Taylor hydrodynamics problem involving a heavy fluid (Mercury) on a lighter fluid (Paraffin Oil). This causes the well-known Rayleigh-Taylor instability. At an early stage the formation of viscous finger due to low viscosity of Mercury relative to Paraffin Oil can be seen. In the sequence of figures below the colour function at different time steps in a cavity of 4m x 1m is shown. A sinusoidal interface is imposed to start the movement. The surface tension development is also applicable to the previous two-phase flow methods in PHOENICS: HOL and SEM.





The new VOF techniques enlarge the field of application for PHOENICS and are available via its VR menu. The surface tension development is also applicable to previous two-phase flow methods in PHOENICS: the HOL and the SEM methods.

References

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