11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20–25, 2014, Barcelona, Spain

# NUMERICAL ISSUES IN HIGHER-ORDER ACCURATE SIMULATIONS OF FLOWS WITH VORTEX CAVITATION

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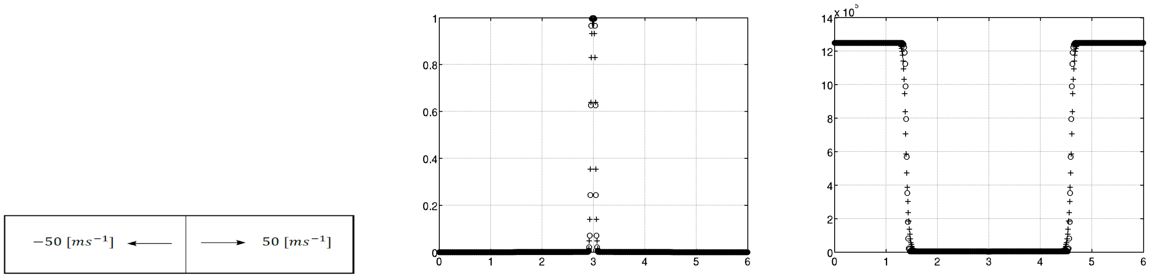
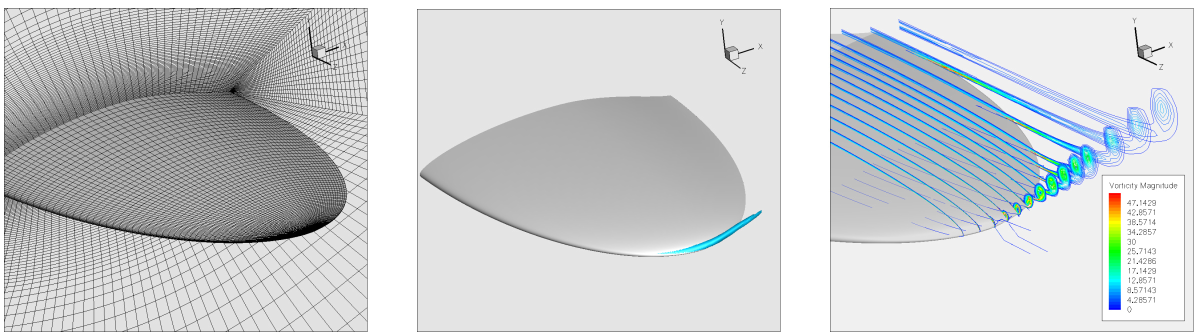
**Key words:** *Cavitation, Vortex, WENO, Positivity.*

This paper, investigates the feasibility of performing a robust numerical simulation of the dynamics of vortex cavitation. The thermodynamic approach is a continuation of the work performed by Khatami *et al.* [1]. An equilibrium cavitation model is employed, which assumes local thermodynamic and mechanical equilibrium in the two-phase flow region. The computational method assumes a compressible flow together with appropriate thermodynamic equations of state. The unsteady compressible Euler equations are employed using a cell-centered structured multi-block finite volume scheme. The viscous terms are not taken into account, because the numerical issues encountered are typically caused by (the discretization of) the inviscid equations. Due to the presence of discontinuities between the different phases of the cavitating flows, using a monotonic reconstruction scheme is necessary for simulations of flows with vorticies. It will be shown that the Monotone Upstream-centered Schemes for Conservation Laws (MUSCL) family of reconstruction schemes are not well-suited for such simulations. More sophisticated technique based on the higher-order Weighted Essentially Non-Oscillatory (WENO) reconstruction schemes, are considered instead, which have proven to be robust in many applications. In order to perform the cavitating flow simulations using WENO schemes, the positiviy-preserving property of the solution must be fulfilled. This is necessary to avoid negative values of density and/or internal energy near large discontinuities between different phases. Zhang *et al.* [2], and Xiangyu *et al.* [3] developed positivity-preserving methods for WENO schemes. In these approaches the limiter functions are used in order to preserve the monotonicity of the solution near the discontinuities. It is well-known that the limiter functions introduce considerable amount of artificial dissipation, which is highly undesirable in vortex cavitation simulations. We propose a non-limiting (no slope/flux limiters) positivity-preserving strategy for WENO schemes, which is rather simple and computationally low-cost. Some




(a) Schematic of the tube (b) vapor void fraction (c) pressure

Figure 1: 1D cavitating expanding waves test case, with the developed ($5^{th}$-order accurate) positivity-preserving WENO (o), and the MUSCL scheme (+). The non-positivity-preserving WENO scheme failed these simulations.




(a) Computational grid (b) Vapor void fraction isosurface for $\alpha = 0.2$ (c) Plane cuts of vorticity magnitude contours

Figure 2: Tip vortex cavitation simulations on Arndt's elliptic hydrofoil for $\sigma = 1$, using a MUSCL reconstruction scheme (MUSCL results are rather diffusive).

test case simulations with or without cavitation are presented to assess the developed positivity-preserving WENO aproach.

## REFERENCES


[1] Khatami, F., van der Weide, E., and Hoeijmakers, H., Multi-phase thermodynamic tables for efficient numerical simulation of cavitating flows: A novel approach towards optimized accurate tables. *8th International Conference on Multiphase Flow, ICMF 2013, Jeju, Korea*, 2013.

[2] Zhang, X., Shu, C. W., Maximum-principle-satisfying and Positivity-Preserving High-Order Schemes for Conservation Laws: survey and new developments. *Proc. R. Soc. A Math. Phys. Eng. Sci.*, Vol. **467**, 2752–2776, 2011.

[3] Xiangyu, Y. H., Adams, N. A., Shu, C. W., Positivity-preserving Method for High-Order Conservative Schemes Solving Compressible Euler Equations. *J. Comput. Phys.*, Vol. **242**, 169–180, 2013.