Development and Validation of the Full Cavitation Model

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Cavitation, a flow phenomenon in which gaseous bubbles form in regions of low liquid pressure, can fundamentally affect the seakeeping performance of marine platforms. A combination of numerical and physical experiments is required to effectively study cavitation and OpenFOAM already has several cavitation models implemented, specifically the Kunz (Kunz et al. 2000), Merkle (Merkle, Feng & Buelow 1998) and Schnerr-Sauer (Schnerr & Sauer 2001) models. These three models are all four parameter models, with the parameters listed in Table 1, and while some of the parameters are nominally physically based they can vary over several orders of magnitude (Erney 2008; Hanimann et al. 2016).

Table 1 – Tunable parameters for OpenFOAM's native cavitation models.

Model	Parameters
Kunz	U_∞, t_∞, C_{prod}, C_{dest}
Merkle	U_∞, t_∞, C_{prod}, C_{dest}
Scherr-Sauer	n, d_{nuc}, C_{prod}, C_{dest}

Our work to date has focused mainly on the Schnerr-Sauer model where we tend to fix both C_{prod} and C_{dest} equal to one and focus on the nucleation site count (n) and nucleation particle diameters (d_{nuc}). We have achieved mixed results as the nominally physical-based parameters still required a degree of tuning.

As an alternative, and building on previous internal work from different studies that used the CFD-ACE+ solver (ESI Group 2017), we implemented and have begun to validate the Full Cavitation Model (Singhal et al. 2002). We note that it appears that a number of groups have attempted this previously but they are either dead projects or have not published their code sources. It is our intent, should the validation complete successfully, and that the community is accepting, that our sources be pushed back to the main tree for inclusion in the public releases.

The initial validation case chosen here was based on the two-dimensional NACA66(MOD) experiments of (Brockett 1966), which has been used extensively for the validation and numerical benchmarking of solver codes against nominally two-dimensional sheet cavitation, for example Baloga (1982), Michael (2013) and Gaggero & Villa (2017). Briefly, these physical experiments were undertaken at the GALCIT High Speed Water Tunnel at the California Institute of Technology, which at that time had a working section 1.27 x

0.152 x 0.762 m and can accommodate speeds up to 30.5 m/s with working tunnel pressures from 689 kPa to vapour (Ward 1976).

Qualitatively the results are encouraging as the pressure fields are as expected, for example Figure 1, and progressively as the free stream pressure is dropped the inception point is reached, Figure 2, through to a fully cavitating foil, Figure 3.

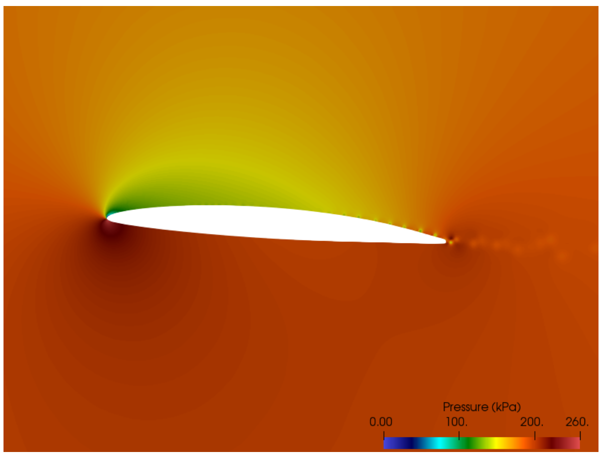

Figure 1 – 186 kPa pressure with no cavitation

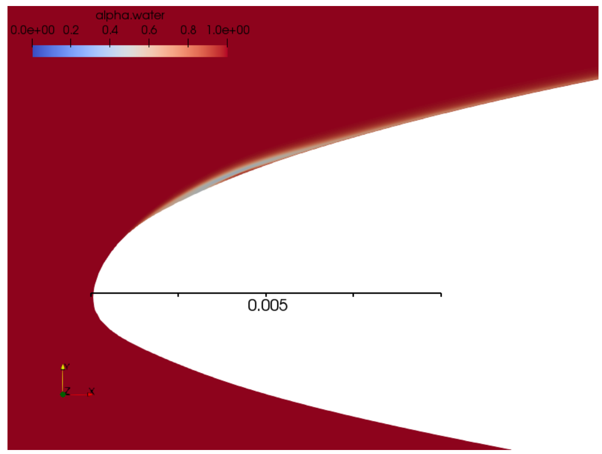

Figure 2 – 120 kPa pressure near inception.

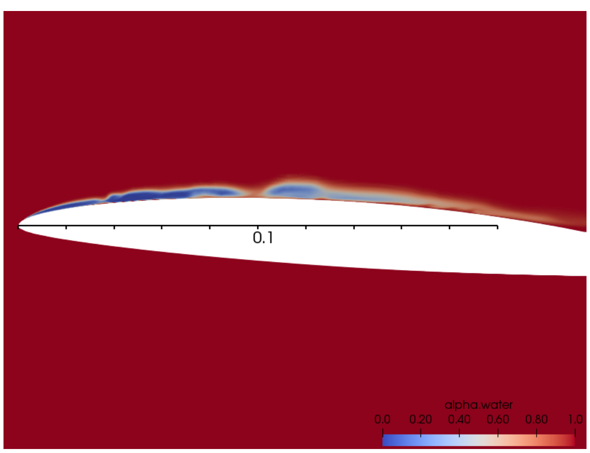

Figure 3 – 60 kPa pressure with extensive cavitation.

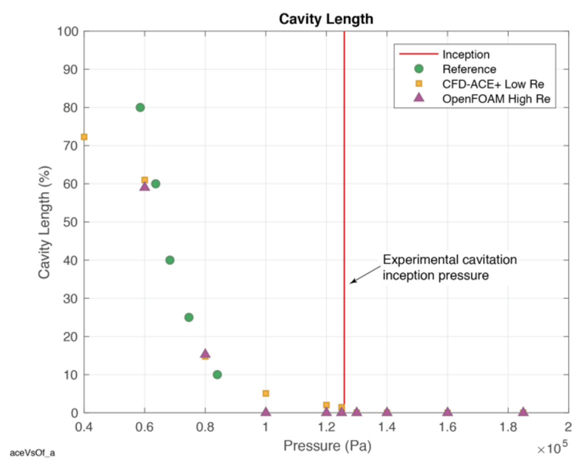

Figure 4 – Measured bubble length verses pressure.

Quantitatively, the measured bubble lengths compare very well with the experiments and reference CFD, as shown in Figure 4. There is a discrepancy in the bubble length near to the inception pressure but we believe this to be related to the grid used in the initial validation. Specifically, we used a high-Re (large y^+) turbulence model and cavitation inception is dependent on the boundary layer, which is simply not adequately resolved with such a turbulence model. In contrast, the reference CFD solution from CFD-ACE+ did use a low-Re (small y^+) model and did resolve the inception point better.

This abstract as outlined our initial work in coding and validating the Full Cavitation Model within OpenFOAM. The initial results are encouraging with good resolution of the cavitation bubble and adequate, to the mesh limits, estimation of the inception point. Development work is continuing and we hope to submit the code for review at a later date.

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