EX206

Cavitating Hydrofoil

Using FLUENT, different cavitation regimes for a 2D hydrofoil have been studied. The calculations were performed for two angles of attack: 6 and 8 degrees, and for a range of flow conditions. Results indicate that certain properties of cavitating flows, such as cavity length and mean lift coefficient, are very well predicted by FLUENT.

A number of 2D simulations have been performed to validate FLUENT for cavitating flows. Two NACA hydrofoils were used and for each, two angles of attack were studied. Results for one of the hydrofoils, the NACA0015, are presented here. The flow conditions were chosen to match experiments performed by the research group of Professor Roger E. A. Arndt at the University of Minnesota. The work was done in collaboration with Associate Professor Morten Kjeldsen at NTNU, The Norwegian University of Science and Technology, Trondheim, Norway. The original measurement descriptions can be found in Reference 1.

Water and water vapor were used in the simulations, and both were treated as incompressible fluids. The flow was treated as laminar, even though the conditions were in the turbulent regime. Plots of vapor void fraction were compared to visual observations recorded on video. Measurements of void cavity length and oscillating and time-averaged lift coefficient were compared to FLUENT predictions.

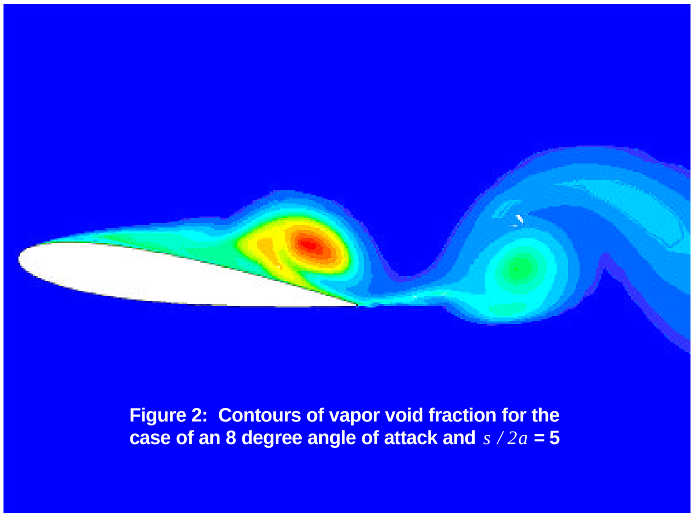

Figure 2: Contours of vapor void fraction for the case of an 8 degree angle of attack and $s / 2a$ = 5

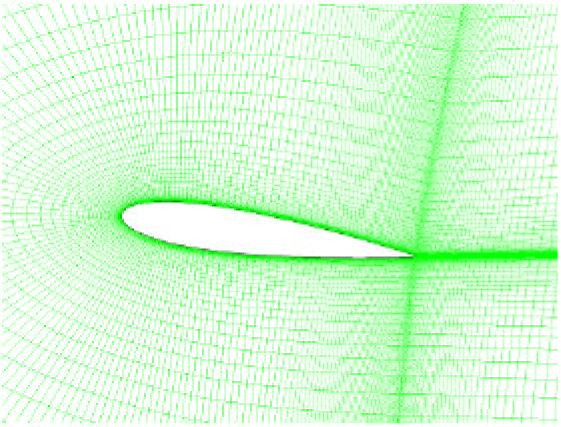

Figure 1: The 2D grid used in the simulation

In cavitation studies, the cavitation number, s, is of interest. It is the ratio of the difference of local static and vapor pressure head to the dynamic head. When divided by twice the angle of attack, $2a$, it forms a parameter that can be used to describe a range of operating characteristics. Values of $s / 2a$, henceforth called the normalized cavitation number, ranging from 2 to 7 were considered in this exercise. In the numerical simulations, the cavitation number was set by varying the inflow boundary conditions. The absolute pressure was of interest in the results, since the onset of cavitation occurs when the absolute pressure drops below the vapor pressure, which is also measured on an absolute scale.

Figure 1 shows a close-up of the 2D grid surrounding the 2D NACA0015 hydrofoil. An instantaneous flow solution showing contours of void fraction is illustrated in Figure 2 for the case of an 8 degree angle of attack and a $s /2a$ value of 5. The

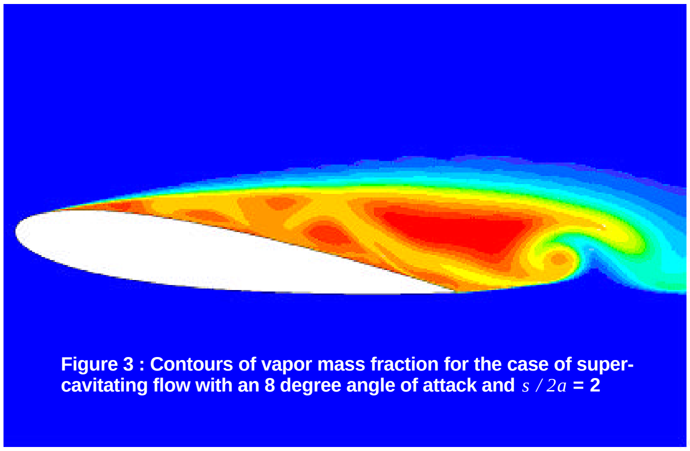

Figure 3 : Contours of vapor mass fraction for the case of super-cavitating flow with an 8 degree angle of attack and $s / 2a = 2$

picture shows a vapor cavity (red) forming inside a flow vortex on the suction side of the hydrofoil. instantaneous contours of void fraction are shown in Figure 3 for the case of supercavitating flow, with $s / 2a = 2$, and an 8 degree angle of attack. Under these conditions, many large vapor cavities form.

Experimental and computed values of normalized time averaged cavity length as a function of normalized cavitation number are shown in Figure 4. Two different angles of attack are considered. For most of the cases studied, the agreement is very good.

The spectrum of shedding frequencies, which are associated with oscillating lift patterns, as a function of normalized cavitation number is shown in Figure 5. Lift breakdown is a major flow feature in cavitating flows and is due to the increased bubble size on the suction side of the hydrofoil. Lift, and especially drag calculations depend on viscous effects, so the choice of turbulence model has a strong impact on the results. This is true for cavitating as well as non-cavitating flows. Despite the fact that laminar calculations were performed, the FLUENT predictions shown in Figure 5 are of the same order of magnitude as the experimental values. Better agreement would have been obtained had a turbulence model been used. Time-averaged predictions of lift (not shown) were found to be in much better agreement with experiment.

In summary, this study has demonstrated that the cavitation model in FLUENT is able to predict the cavity extent in basic hydrofoil flows with reasonably good accuracy. Predictions of cavity size and shedding characteristics were in good agreement with video recordings. There were discrepancies regarding the spectrum of shedding frequencies, but these were most likely due to simplifications made in the simulations, such as the assumptions of incompressible and laminar flow. Bulk quantities like time-averaged lift were reasonably well predicted, however.

Reference:

1. Berntsen G. S., Kjeldsen M. & Arndt R. E. A., Numerical modeling of sheet and tip vortex cavitation with FLUENT 5, Presented at Cav 2001, June 20-23 2001, California Institute of technology, Pasadena, CA, USA.

Courtesy of The Norwegian University of Science and Technology

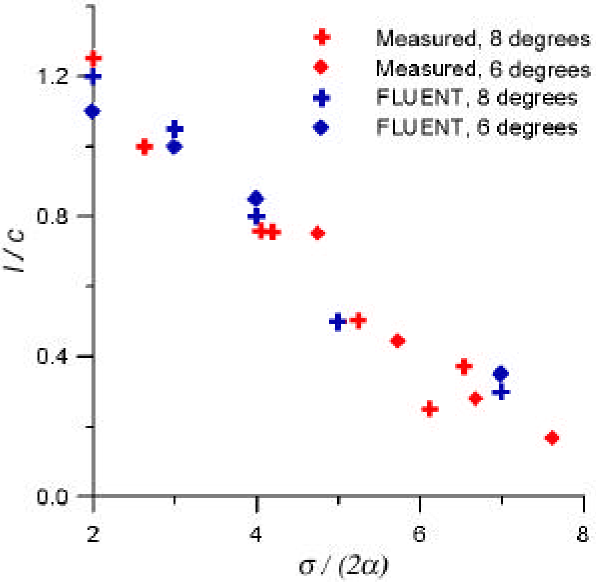

Figure 4 : Normalized time averaged cavity length as a function of normalized cavitation number

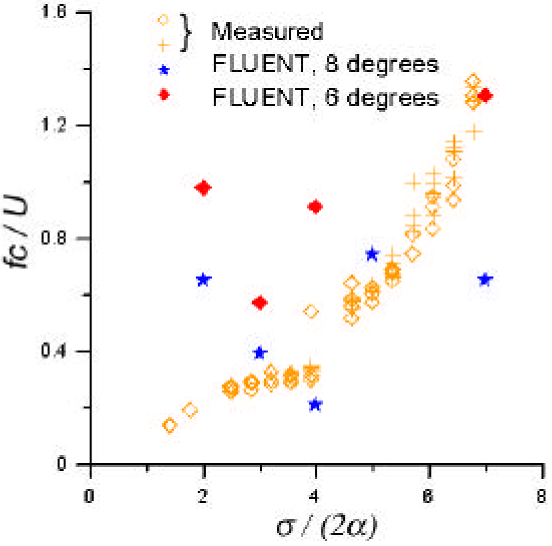

Figure 5: Frequency spectrum for lift oscillations as a function of normalized cavitation number