# Horseshoe Cloud **Cavitation**

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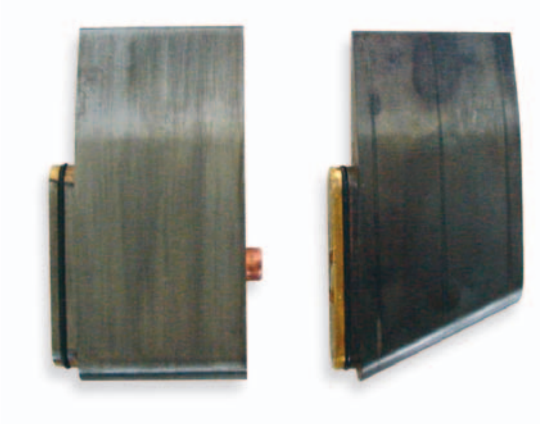

For water pumps, marine propellers, and other equipment involving hydrofoils, cavitation can cause problems such as vibration, increased hydrodynamic drag, pressure pulsation, noise, and erosion on solid surfaces. Most of these problems are related to the transient behavior of cavitation structures. To better understand these phenomena, unsteady 3D simulations of cavitating flow around single hydrofoils have been performed, and the results have been compared to experiment. The symmetric hydrofoil studied was 50 mm wide, 108 mm long, 16 mm thick, and had a circular leading edge and parallel walls. It was subjected to a steady incoming flow of 13 m/s at an incidence angle of 5°. The highly turbulent flow was simulated using the RNG k-ε model on a structured mesh of 360,000 cells.

The cavitation model in FLUENT was used. For the first set of simulations performed, the transient calculation predicted the onset of cavitation, and revealed an initial fluctuation of the cavity volume, with a subsequent quasi-steady stabilization of a cavitation sheet. The overall length of the predicted cavity structure was found to be about 50% too short, however, when compared to the experimental results. The problem was due to the overprediction of turbulent viscosity in the region of cavity closure.

To improve the agreement, a modification of the turbulence model was applied using user-defined functions (UDFs). The turbulent viscosity of the mixture was artificially reduced by using a power law function for density [1,2]. The modification simply states that the turbulent viscosity falls faster with decreasing density (increasing vapor volume fraction) than it would if no modification were made. This modification limited the kinetic energy in the region filled mainly by the vapor phase. The reduced kinetic energy allowed the formation of a re-entrant jet and promoted the separation of a cavitation cloud. A typical "horseshoe" vapor structure – observed during the experiment and considered to be the driving mechanism for cavitation erosion – was correctly predicted by the simulation once the modifications were made.

Measurements [3] of the mean transverse velocity profiles at several axial stations were compared to the CFD results. The best agreement was found to be just past the leading edge of the hydrofoil, where the vapor volume fraction is substantial. The experiments and CFD simulations also captured a small region of back flow. Downstream, the agreement was not as good, but the same trends were still in evidence.

Additional simulations were done using a hydrofoil with a swept leading edge. The results were found to be similar to the experimental findings, including significant dynamic cavitation near the front wall, with pulsations of the cavitation region and the separation of a cavitation cloud. Steady, yet weaker cavitation with no cloud separation was predicted (and measured) near the rear wall.

Current work includes the development of a numerical cavitation erosion model, with a future goal of being able to predict dynamic cavitation effects, like cavitation erosion, using only CFD. ■

## references:

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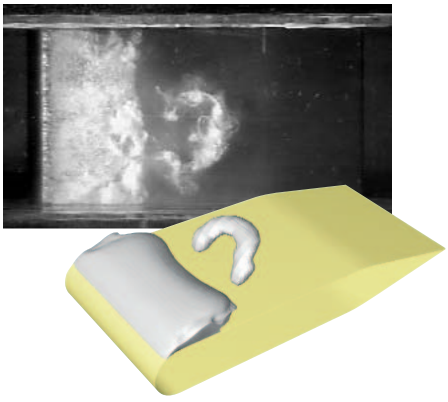
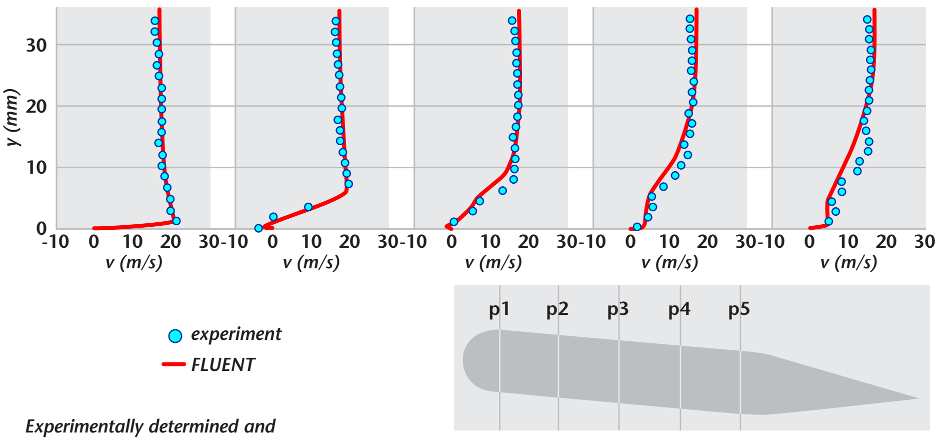
3 R. Bachert, G. Ludwig, B. Stoffel, M. Frobenius, R. Schilling, "Three-Dimensional Unsteady Cavitation Effects on a Single Hydrofoil and in a Radial Pump – Measurements and Numerical Simulations; Part One: Experiments," Proceedings of the Fifth International Symposium on Cavitation, Osaka, Japan, 2003.



*The experimentally determined (top) and simulated (bottom) "horseshoe" cavitation structure*



*Experimentally determined and simulated velocity profiles*