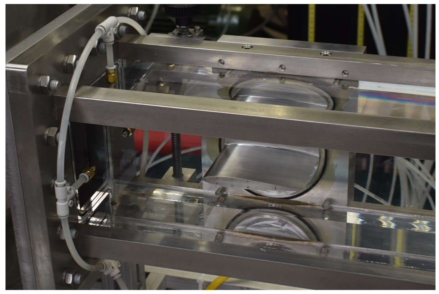
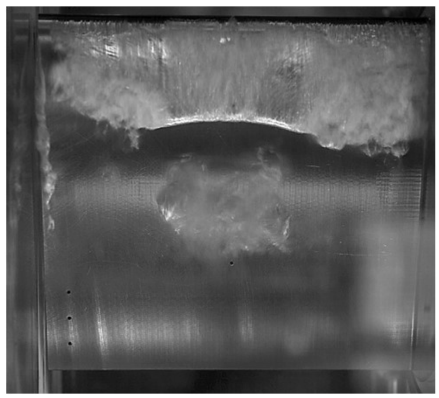
HSLU Hochschule Luzern

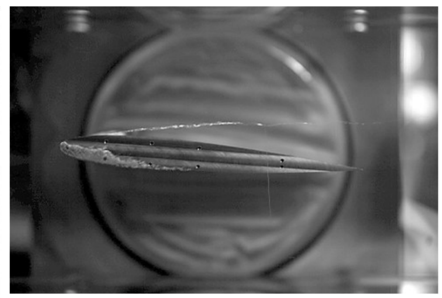
Technik & Architektur
Energy Systems Engineering

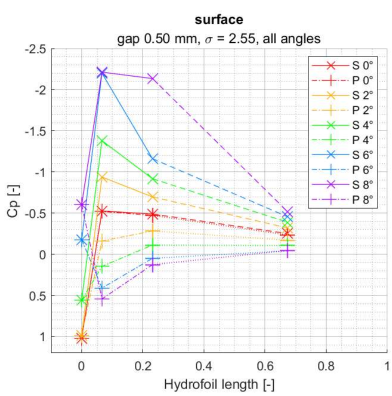
Bachelor‘s Thesis in Energy Systems Engineering

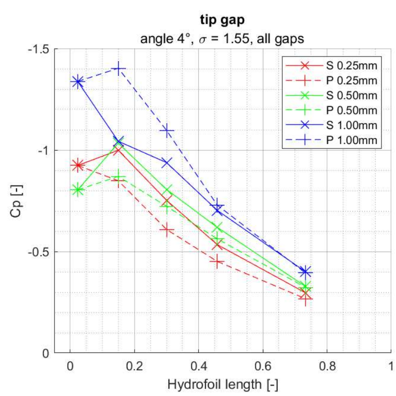
Experimental study of cavitating flows around a hydrofoil











Background

Cavitation is the development and subsequent collapse of vapor-filled cavities within a flow of liquid, triggered by the local pressure falling below the vapor pressure. This phenomenon is of high importance in fluid machinery, as it causes several undesirable effects if not managed properly, including loss of performance and damage to the equipment. In this study, the flow around a NACA 0012 hydrofoil is investigated under different cavitation conditions.

Objectives

- Measurement of the pressure distribution around a NACA0012 hydrofoil for various conditions.
- Flow visualization of the same flow conditions using regular and high-speed camera.
- Determining the extent and type of cavitation for each flow condition using the high-speed recordings.
- Confirming whether the measured pressure distributions are in accordance with expectations.
- Understanding the effect of tip gap on cavitation behavior.
- Providing test data to the CC FMNM for CFD model verification.

Experiment setup

The measurements were executed using the pump test rig of the CC FMNM. In a closed system, water is circulated at a fixed flow rate and the hydrofoil is placed between a large pressure tank and the pump, into a duct with a square cross-section, made of plexiglass. On one side, there is a narrow gap between the hydrofoil and the wall, simulating the tip clearance in turbomachines. The angle of attack can be adjusted as well as the pressure inside the tank, which corresponds to the total pressure of the flow.

The local pressure is measured at 19 locations on the hydrofoil placed on the center of both sides, inside the gap, and in the rear corner adjacent to the gap. The flow is subsequently recorded from three angles using a high-speed camera with framerates of 5400 or 8000 fps.

Important non-dimensional quantities

The recorded pressure values are represented by the non-dimensional pressure-coefficient:

$$C_{P\,(x)} = \frac{P_{(x)} - P_{ref}}{\frac{1}{2}\rho\, u_{ref}^2}$$

The cavitation parameter σ can be used as a similarity parameter for cavitating flows. In general, a flow with higher σ is less susceptible to cavitation. All possible values of Cp are theoretically limited by –σ.

$$\sigma = \frac{P_{ref} - P_v}{\frac{1}{2}\rho\, u_{ref}^2}$$

Findings

The measured pressure distributions are mostly in accordance with expectations. As the definition suggests, Cp appears to be independent of σ as long as the flow does not cavitate. It has also been confirmed that if no cavitation is present, the pressure difference between the two sides is proportional to the angle of attack. When cavitation occurs at a certain point, the pressure there is set by the vapor pressure. (Cp=-σ.) This means cavitation diminishes the lift force generated by the hydrofoil.

Different types of cavitation were observed. Attached cavitation was present for high angles, and bubble cavitation for low pressure. It has been found that for some pressures and angles, the cavitation sheet will periodically detach, forming a cavitation cloud and subsequently re-develop from the front of the hydrofoil. The frequency is in the 30-130 Hz range, depending on the exact conditions. This oscillation also slightly influences the pressure measurement.

The flow inside the narrow tip gap is very complex but it appears that cavitation within this region is only present for gap widths of more than 0.25 mm (0.25% of hydrofoil width) At gap widths of 0.50 and 1.00 mm, vortex cavitation was also observed, likely triggered by the increasing flow rate trough the gap. Some observations remain to be explained.

Lorant Sztranyovszky

Supervisor:
Dr. Sabri Deniz

Cooperation partner:
HSLU CC Fluid Mechanics and Numerical Methods

FH Zentralschweiz