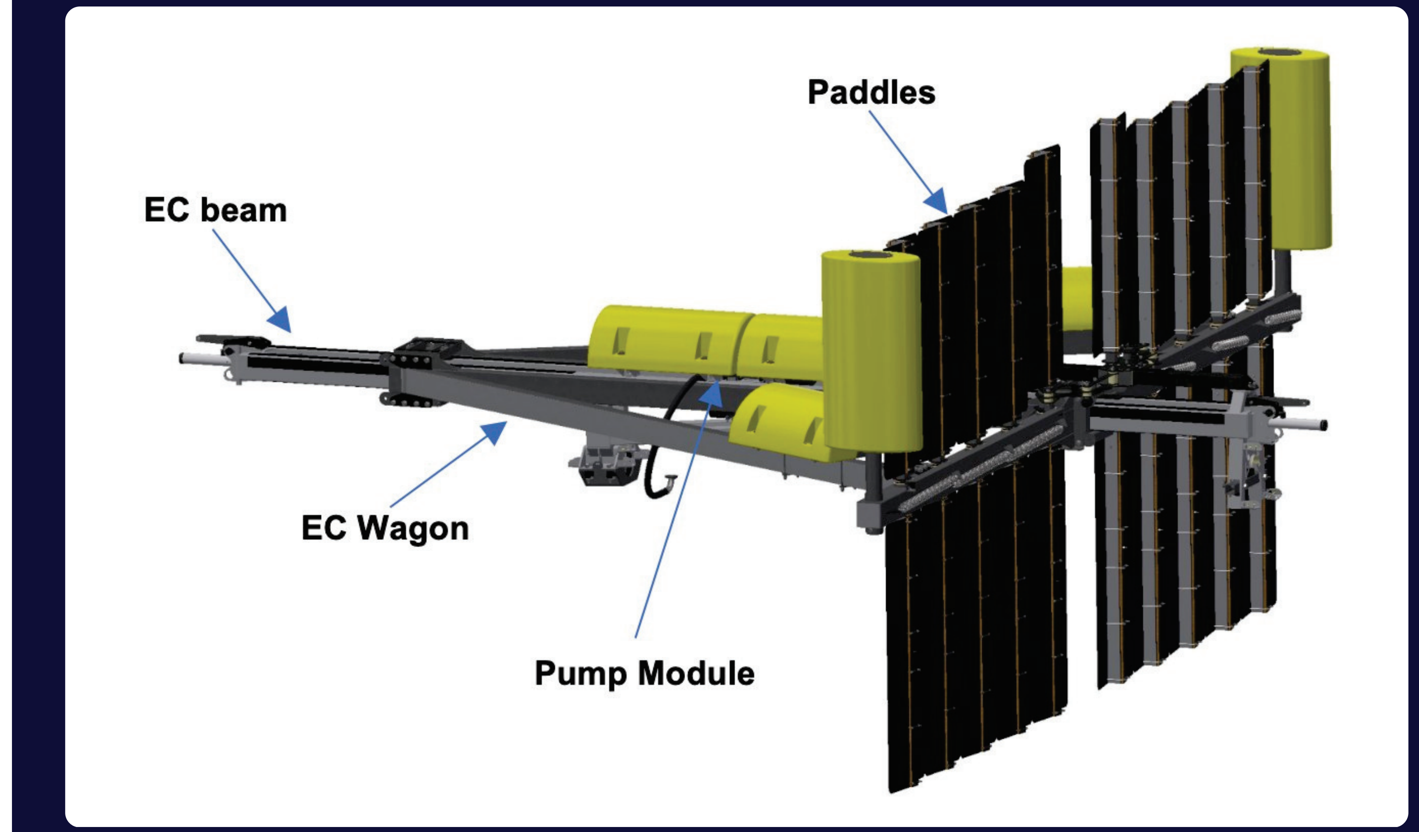
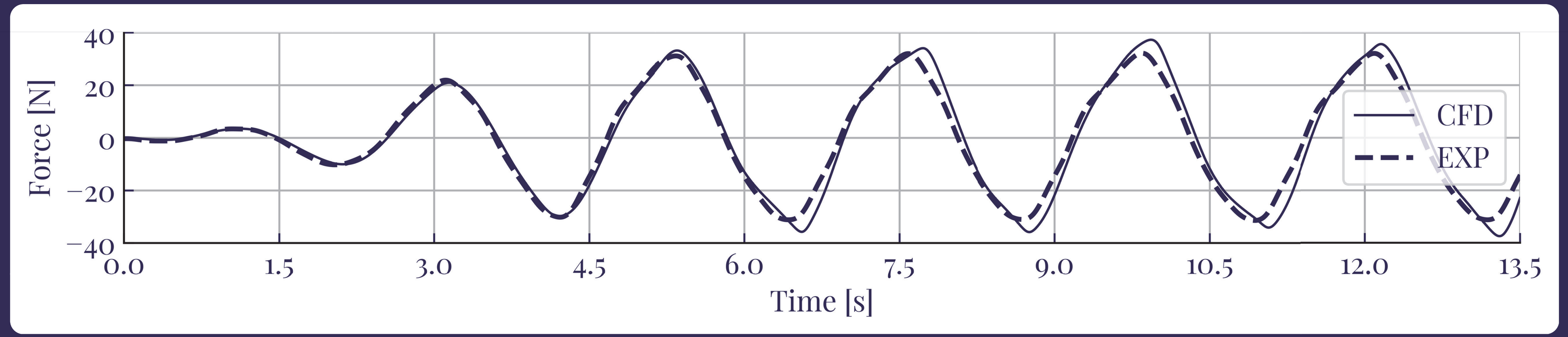
Analysis of Rigid and Flexible Sails in an Oscillating Wave Surge Converter

Investigating the hydrodynamic performance of rigid and flexible sails in a OWSC through CFD modelling and experimental video analysis



The ***Wavepiston*** system is an Oscillating Wave Surge Converter (OWSC) that captures wave energy through the motion of vertical sails, made up of interconnected plates or paddles. These sails drive a hydraulic pump, which delivers pressurised seawater to an onshore turbine or desalination plant. During storm conditions, added mass effects can result in high hydrodynamic loads and abrupt hard stops at the end of the sail's motion, placing severe mechanical stress on the pump system. The ***COHSI-WEC*** project addresses this issue by introducing flexible sails that deform under wave pressure, reducing their effective surface area.

This thesis explores the behaviour of rigid and flexible sails. A CFD model of a rigid sail was developed using a symmetry plane to reduce computational cost. Additionally, a custom video analysis script was developed to extract sail deformation data from underwater footage, offering qualitative insight where direct measurement during lab testing was not possible.

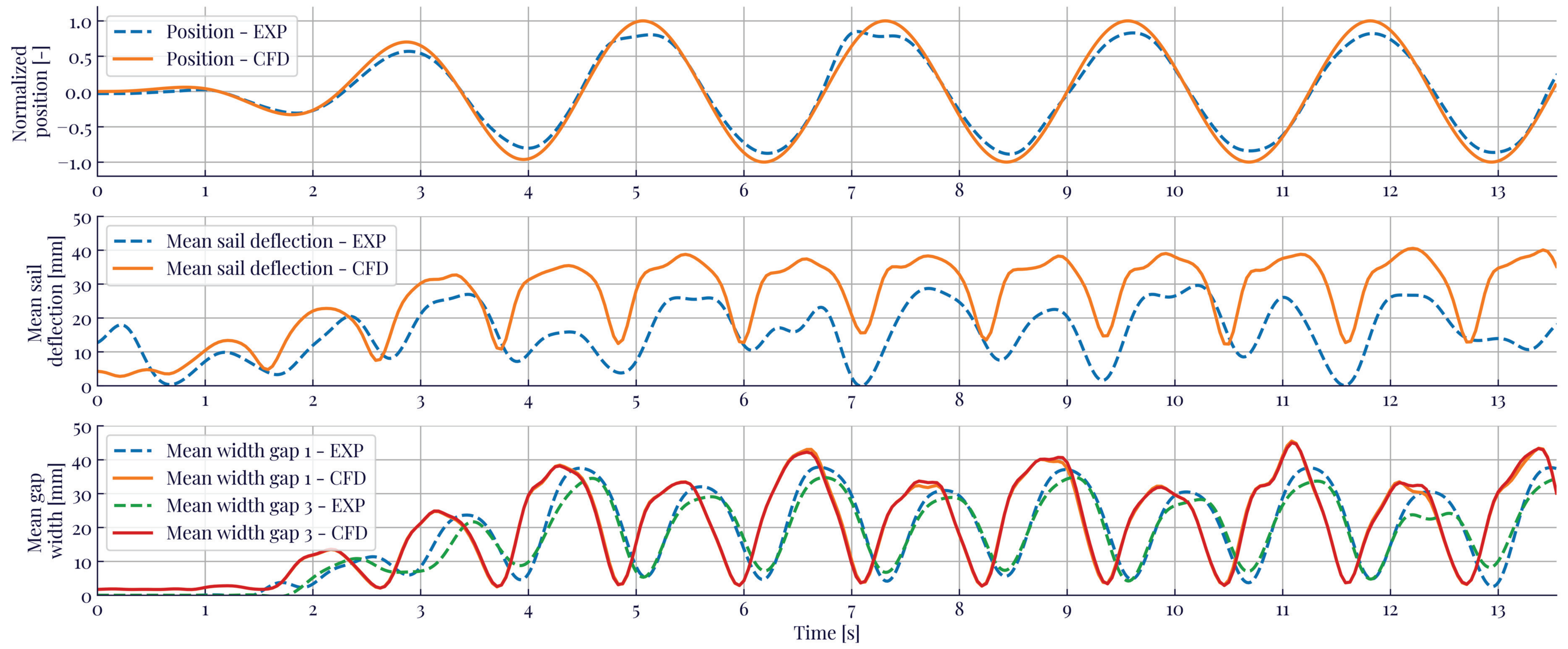


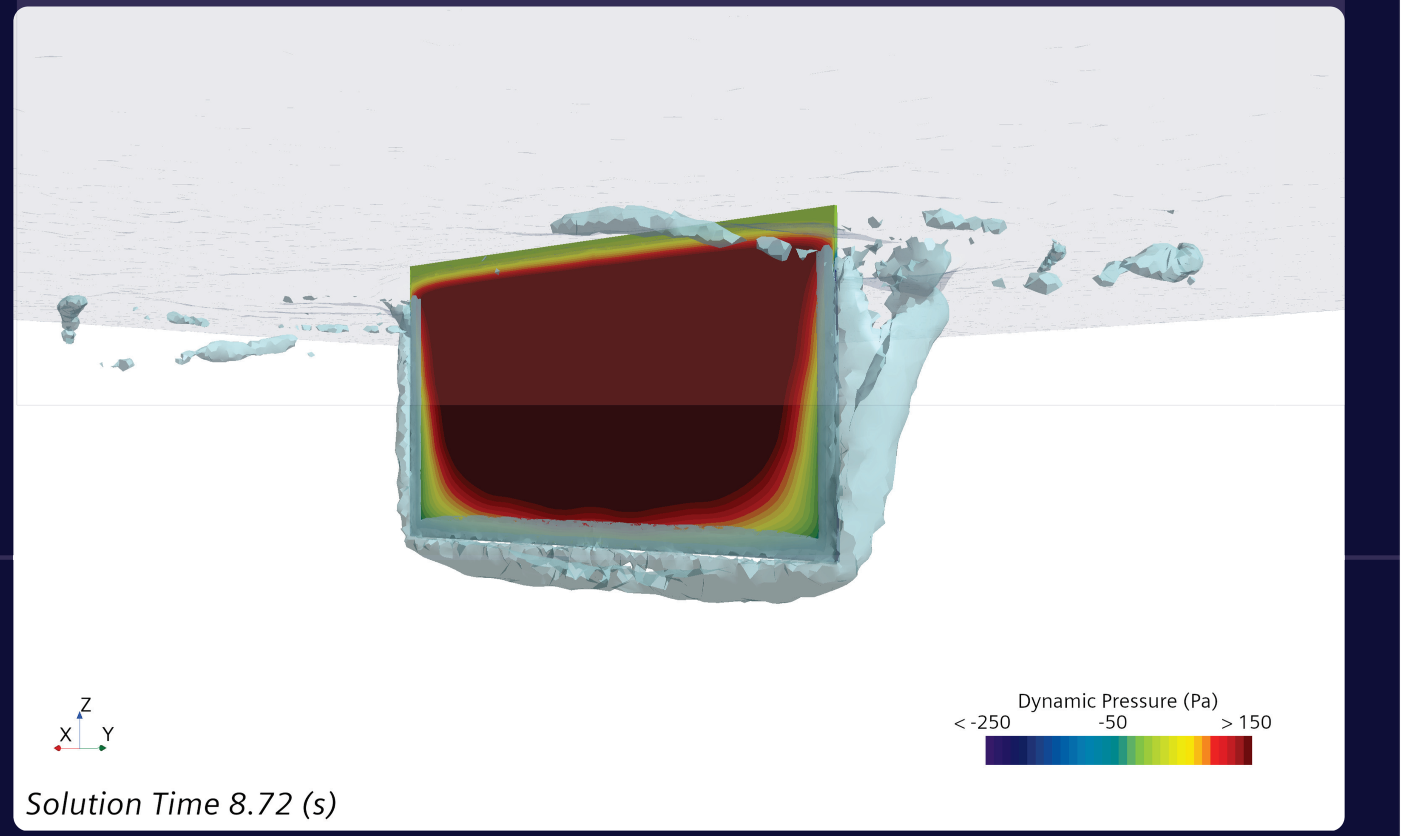
Rigid Sail - CFD Modelling

A one-way coupled CFD model was developed in STAR-CCM+ to simulate the hydrodynamic forces acting on a rigid sail during oscillatory motion in still water. The simulation and the corresponding physical experiments were conducted at 1:16 Froude scale. To reduce computational cost, only half of the domain was modelled using a symmetry plane. The model used the Volume of Fluid (VOF) method to track the water–air interface and a hybrid URANS–LES turbulence model to resolve flow separation and vortex shedding around the sail. The results from the CFD model were validated against the data obtained from the physical experiments performed in the wave laboratory.

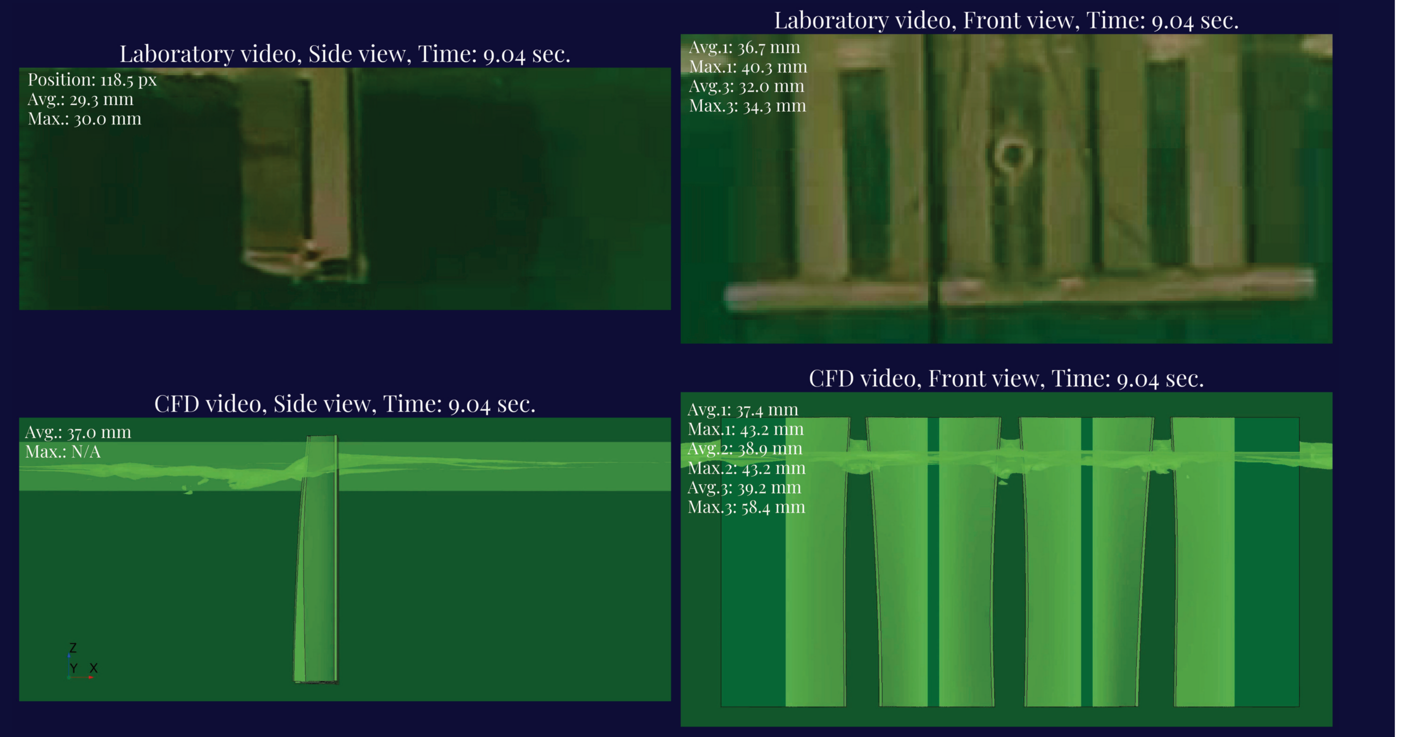
Flexible Sail - Video Analysis

A custom Python script was developed to extract deflection data frame-by-frame from the experimental videos. The analysis was based on edge detection technique Canny filter via the OpenCV library. Known reference dimensions were used to convert pixel measurements to physical units. The output data is the mean sail deflection as seen from the side view and gap widths as seen from the front view.





The experimental video results were compared to a two-way coupled CFD model developed outside this thesis. While the video data contains some variability, the observed trends align well with the simulation, supporting the use of video analysis as a qualitative validation method.



Bogdan Bernic
M.Sc. Structural and Civil Engineering, Aalborg University
June 2025