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INVESTIGATION OF CAVITATION EROSION WITH A DENSITY-BASED CFD-METHOD ON A HYDROFOIL WITH CIRCULAR LEADING EDGE

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A hyperbolic flow solver together with the statistics of vapor dynamics and detection of void collapses is utilized for the prediction of flow aggressiveness in dependence on cavitation number. Good qualitative agreement with experimental results is achieved regarding erosion sensitive wall zones.

Introduction

Erosion is one of the most serious consequences of cavitation in hydraulic machinery. The most aggressive type regarding cavitation erosion is cloud cavitation, which occurs on the circular leading edge (CLE) hydrofoil (see Fig. 1) for the chosen range of cavitation numbers σ between 2.0 and 2.5 at Reynolds number 1,300,000. Due to the similarity of the CLE-profile and pump blades, it is an adequate test case for pump flow.

Figure 1: CLE hydrofoil

Method

A CFD-method is chosen that is able to capture and resolve the relevant physical phenomena of cavitation erosion such as shock waves and compressibility effects.

Flow solver:

- Density-based, compressible.
- Explicit time integration.
- Flux function for cavitating flow [1].

Physical models:

- Equilibrium cavitation model via barotropic equation of state [2], realized as look-up table for efficiency.
- No explicit turbulence model.

Assessment of cavitation erosion:

- A) By flow structures: Binary void fraction field (see Fig. 2), RMS evaluated for many snapshots.
- B) By detection of void collapses [3] as a verification of method A).

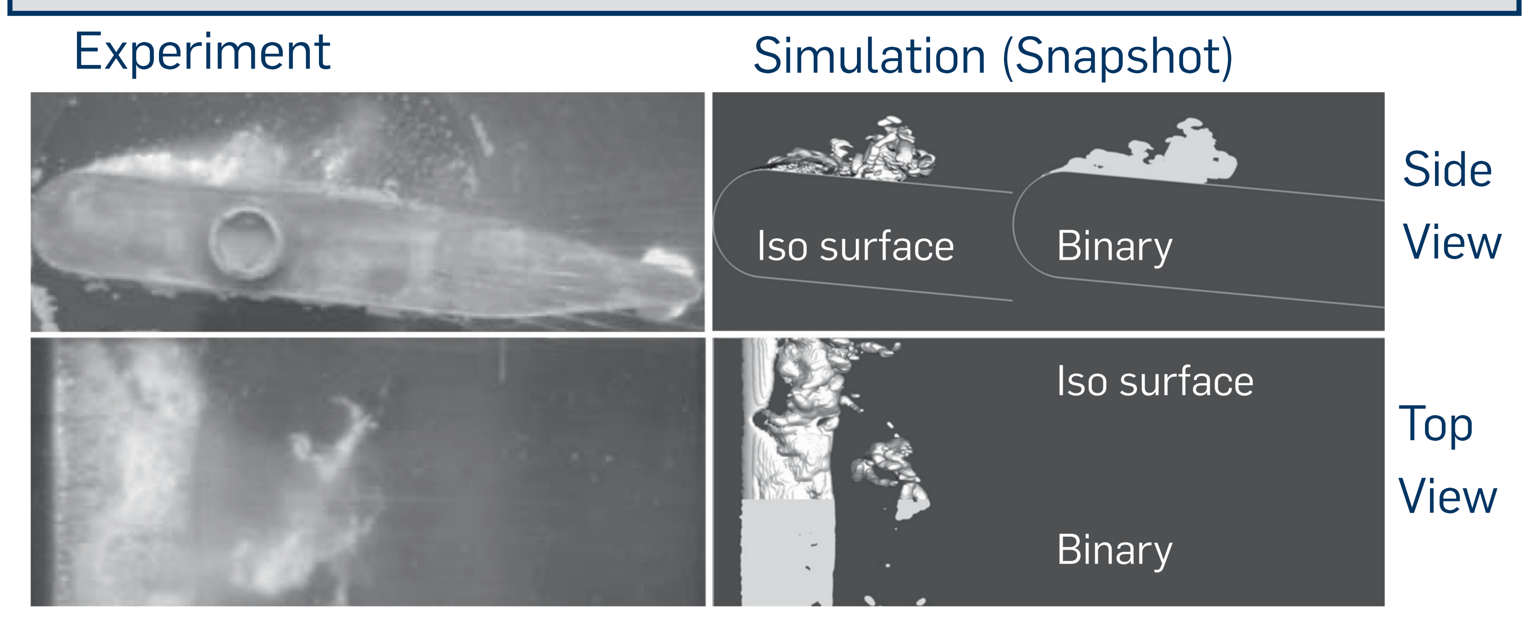

Figure 2: CCD-Images of the experiment [4] and snapshots of the simulation, for which the iso surface of vapor volume fraction with value 0.05 is binarised for the side and top view.

For method B), the collapses near the hydrofoil wall have been identified and analyzed statistically, yielding a load collective, i.e. cumulative collapse rate ccr vs collapse pressure p_{coll} (Fig. 3 left). In order to obtain local

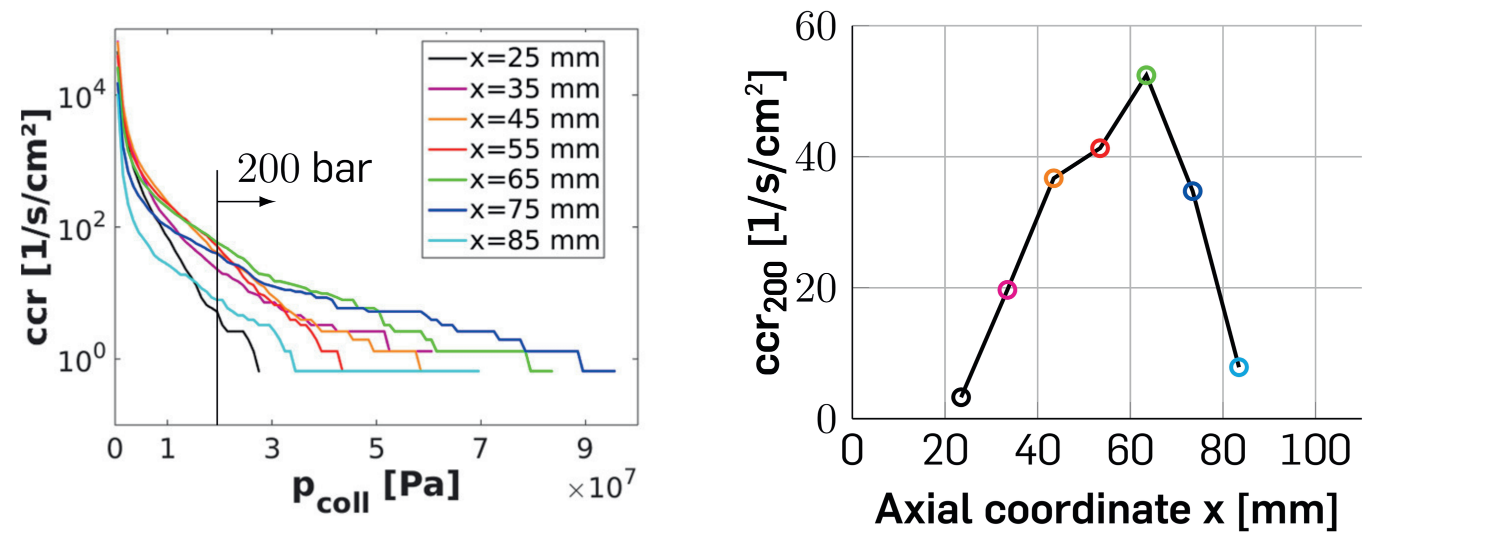

Figure 3: Exemplary evaluation of detected collapses by method B) plotted as cumulative collapse rate ccr over collapse pressure p_{coll} for different streamwise segments of length Δx = 10 mm. Only near-wall collapses above a threshold value of 200 bar are taken into account to yield local information about erosion sensitive wall zones.

information about erosion sensitive wall zones, the procedure for axial segments described in Fig. 3 is utilized.

Results

In Figure 4 a), both in the experiment and simulation with increasing cavitation number erosion occurs further upstream and is concentrated to a smaller area.

In the experiments [5] a correlation has been found between vapor dynamics and erosion sensitive wall zones: High gradients of average values and high RMS values correspond to erosion sensitive wall zones. For the simulation the same comparison is made in Fig. 4 b) and c). The vapor dynamics and erosion sensitve wall zones also show good agreement. Flow aggressiveness can be defined as area under the ccr_{200} curve in Figure 4. For both experiment and simulation the highest load is observed for $\sigma = 2.3$.

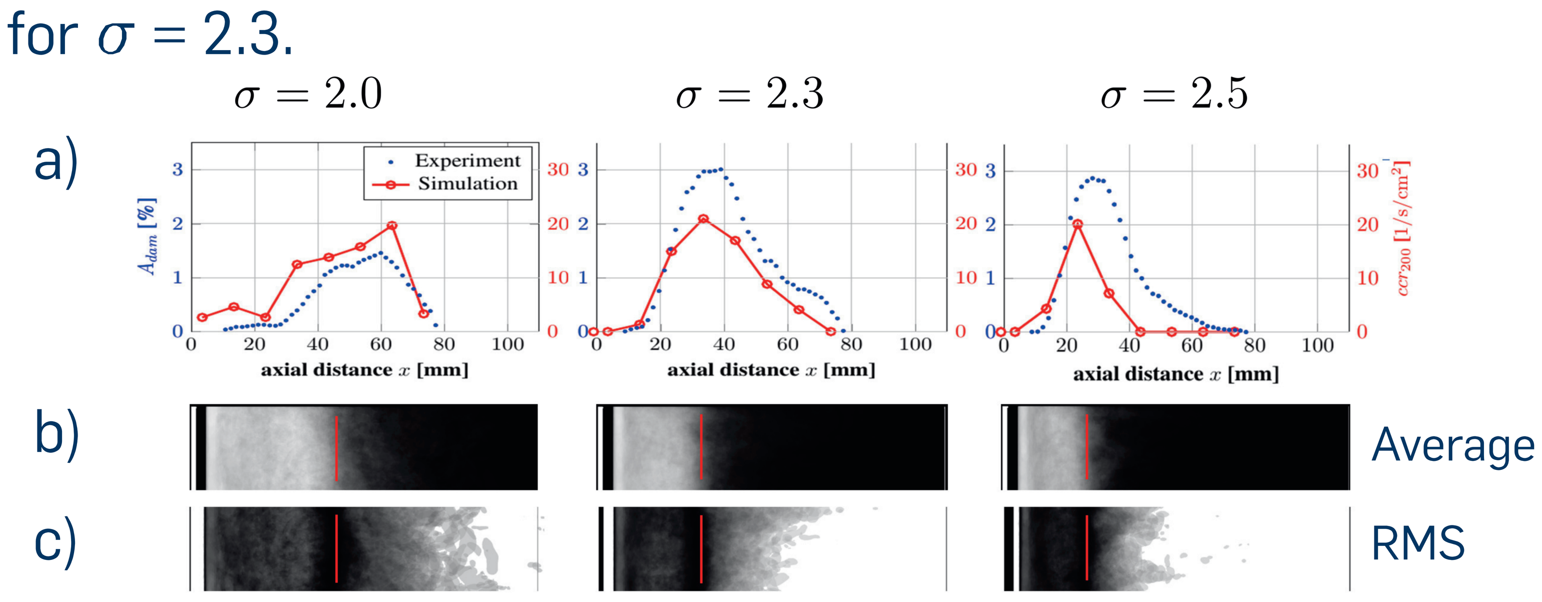

Figure 4: a) Damage (= percentage of pitted area) averaged over span from the experiment and erosion sensitive wall zones from the simulation by local evaluation of the number of collapses (ccr above 200 bar, method B). b) Average and c) RMS values of vapor iso surfaces in the top view. Red lines indicate high gradients of average and high values of RMS.

Conclusion

Both the RMS of the void fraction field (vapor dynamics) as well as the local number of collapses are good indicators for erosion sensitive wall zones. The latter is an accurate albeit expensive means in order to assess flow aggressiveness. The former opens the perspective to a less resource-consuming engineering method since it can even be used in combination with implicit CFD methods.

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