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Estimation of Incubation Times through Numerical Simulation of 3-D Unsteady Cavitating Flows

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ABSTRACT

We present recent progress concerning the prediction of cavitation erosion with the help of numerical simulation of 3-D unsteady cavitating flows. In previous investigations [1] our numerical tool CATUM showed promising potential for identifying erosion endangered areas, even within complex flow fields. As a next step we introduced an approach to identify and quantify single collapse events during our simulation, referred to as “collapse detector” [2]. The generated data result in information about a time history of collapse events including associated collapse pressures, which represents a possible load profile that the material is exposed to.

In the present investigation we use the collapse data as input for an analytical material model introduced by Karimi [3]. By doing so we compute spatially resolved incubation times of the material. This step delivers a yet missing component within our prediction procedure, as the quality of the generated information increases from a qualitative identification of a potential “erosion risk” to a quantitative statement concerning material fatigue. Our predictions are compared to experimental findings.

TESTCASE

We simulate an experiment reported in [4]. The axisymmetric setup consists of a nozzle, which is directed onto a target forming a radial divergent gap (figure 1). At the exit of the nozzle the fluid accelerates along a small radius and forms a transient radial cavitation pocket, which is strongly non uniform in circumferential direction. The collapse of the cavitation pattern leads to an annular shaped erosion damage on the target (figure 2).

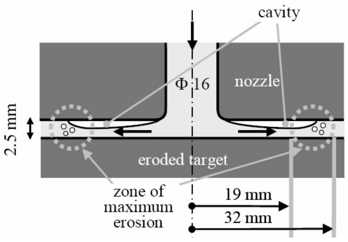

Figure 1: Sketch of the experimental setup [4].

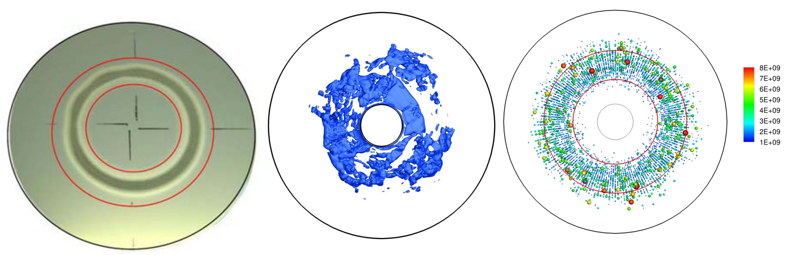

Figure 2: A) Photograph of an eroded target from the experiment. Area where damage was reported is marked in red [4]. **B)** Single time instant showing iso-surfaces of the vapor volume fraction (α=0.1) View in direction of the nozzle flow, normal to the gap between nozzle and target. **C)** Visualization of all collapses detected during an analysis interval. Each collapse is represented by a sphere at the position of its occurrence. Size and color represent the collapse intensity.

UNDERLYING NUMERICAL METHOD

We apply our flow simulation tool CATUM (CAvitation Technische Universität München [5]), which is a density-based finite volume method employing a low Mach number consistent flux function and an explicit time marching procedure. The working fluids can be characterized by closed form equations of state, or for complex fluids by look-up tables. In order to allow for the simulation of shock formation and wave propagation, the compressibility of the fluids (liquid and vapor) is taken into account. The phase transition model is based on local equilibrium assumptions for pressure, temperature, and specific Gibbs functions. Previous investigations [6] show that CATUM is able to predict even delicate flow features, such as irregular break-up patterns of partial cavities of developed cavitating flows.

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