CFD data of unsteady cavitation around a hydrofoil, based on an extended Schnerr-Sauer model coupled with a nucleation model

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1. Data

CFD data concerning the dynamics of the vapor cavity over a temporal cycle of birth, growth, detachment and collapse are provided. Furthermore, the temporal signals and the FFT spectra of the spatially averaged liquid volume fraction \( \alpha \), the lift coefficient \( C_L \), the drag coefficient \( C_D \) and the static pressure upstream derived from a virtual probe located 0.1 m upstream and placed along the...
symmetry axis of the duct. In addition, the temporal signals of the cavity lengths estimated by thresholding at 0.9 are given. The average, minimum and the maximum cavity length are also documented. In particular the average cavity length has been derived by thresholding at 0.9 of the average field of $a$, while the minumum and the maximum correspond to the minimum and the maximum elongations of the vapor cavity. They are compared with the experimental data provided by Ref. [2], which have been derived by averaging of acquisition at a sampling rate of 30 fps.

In summary, the supplementary file includes the following data:

1 dataset of the snapshots of the contour field of the liquid volume fraction, the turbulent kinetic energy, the baroclinic vorticity and the dilatation vorticity, over a typical vapor cavity cycle during bubble cavitation at $\sigma=2.1$ (File1), cloud cavitation at $\sigma=1.5$ (File2), and supercavitation at $\sigma=1.2$ (File3);

2 temporal evolution (sampling rate of $F_s=1000Hz$) at $\sigma=1.2$ (column 2), $\sigma=1.5$ (column 3) and $\sigma=2.1$ (column 4), of the
   1 liquid volume fraction spatially averaged over the vapor cavity area developed into an investigation windows extended 0.01 m upstream and 0.125 m downstream with respect to the leading edge of the profile (File4);
   2 lift coefficient (File6);
   3 drag coefficient (File8);

3 FFT spectra (sampling rate of $F_s=1000Hz$) at $\sigma=1.2$ (column 2), $\sigma=1.5$ (column 3) and $\sigma=2.1$ (column 4), of the
   1 liquid volume fraction spatially averaged over the vapor cavity area developed into an investigation windows extended 0.01 m upstream and 0.125 m downstream with respect to the leading edge of the profile (File5);
2 lift coefficient (File7);
3 drag coefficient (File9);
4 static pressure upstream derived from a virtual probe located 0.1 m upstream and placed along the symmetry axis of the duct (File11);
4 temporal evolution (sampling rate of Fs=100Hz) at $\sigma=1.2$ (column 2), $\sigma=1.5$ (column 3) and $\sigma=2.1$ (column 4), of the cavity length Lcav obtained with thresholding at $\alpha=0.9$ (File12);
5 average, minimum and maximum dimensionless cavity lengths Lcav/c ($c$ is the hydrofoil chord, $c=0.115$ m), in comparison with the experimental maximum Lcav/c by Ref. [2](File13).

2. Experimental design, materials, and methods

A water flow around the NACA 0015 hydrofoil was investigated at 298K and in different cavitating conditions. Numerical simulations were performed by using the open source CFD toolbox OpenFOAM Version 3.0.1 [3], based on a Finite Volume formulation. The PBE model has been constructed on the code OpenQBMM v2.0.0 [4]. Based on a probabilistic number density function (NDF) uniquely determined by means of a moment inversion algorithm, which relates the local nuclei density to the nuclei diameter, the PBE is solved by means of the extended quadrature method of moments (EQMOM), which ensures a good accuracy with a reduced computational cost.

The k-\omega Shear Stress Transport model (SST) was chosen owing to its good performance in dealing with confined flows.

The water flow was simulated by using a fixed time step of $1 \times 10^{-4}$ s. In addition, a dual time stepping was introduced in order to solve the population balance equation. In particular, the original time step was decomposed into $N_{\text{subcycle}}=30$ subcycles so as to determine a reduced time step.

The computational domain consisted of 93172 cells and extended $3c$ ($c$=chord length) upstream of the leading edge and $5c$ downstream of the trailing edge of the hydrofoil, and the chord of the hydrofoil is 0.115 m.

The flow was confined in a rectangular duct having a height of 0.12 m. The no-slip condition was imposed on the hydrofoil, as well as on the upper and bottom walls. The initial temperature field was set to 298 K. The inlet velocity of the flow was fixed at 4 m/s. The outlet pressure was derived from the cavitation number $\sigma$ defined as:

$$\sigma = \frac{p_\infty - p_{\infty, 0}}{0.5 \rho U_\infty^2}$$ (1)

Concerning the boundary conditions, unsteady computations were initialized by means of the non-cavitating steady-state solutions, which in turn were constrained by setting the inlet velocity and the pressure outlet with values in accordance with [2]. In particular, the no-slip condition was imposed on the hydrofoil, as well as on the upper and bottom walls. Furthermore, the velocity of the flow was fixed at 4 m/s, which corresponds to a Reynolds number equal to $5.14 \times 10^5$. Using the Reynolds number and the fluid velocity at the inlet upstream, namely $Re$ and $U_\infty$, the turbulent kinetic energy $k$ and the specific dissipation rate $\omega$ were initialized as follows:

$$L_t = 0.16 \ Re^{-1/8}$$ (2)

$$L_t = 0.7 \ c$$ (3)

$$k = \frac{3}{2} (U_\infty L_t)^2$$ (4)
\[ \omega = C_{\mu}^{1/4} k^{1/2} / L_t \]  

(5)

where \( c \) is the hydrofoil chord, \( I_t \) is the turbulence intensity, \( L_t \) is the turbulent length and the coefficient \( C_{\mu} \) was set to its default value equal to 0.09. The outlet pressure was derived from the cavitation number \( \sigma \) defined in Eq. (23). The initial temperature field was set to 298 K.

The characterization of the cavitating flow regimes concerned three different cavitation numbers corresponding to different cavitation regimes: \( \sigma = 2.1 \) (bubble cavitation regime), \( \sigma = 1.5 \) (cloud cavitation regime) and \( \sigma = 1.2 \) (supercavitation regime).

The database of the National Institute of Standard and Technology (NIST) [5] was used for the determination of saturation and transport properties of water.

The data predicted by the numerical model were analyzed by statistical and frequency analysis.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dib.2019.104226.

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