The INSEAN E779a Propeller Test Case: a Database For CFD Validation

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In the last few years, remarkable improvements in numerical modeling of viscous flows around marine propellers have been obtained. In particular, Reynolds Averaged Navier-Stokes (RANS) equation solvers start to be widely used to analyze viscosity effects on propulsors at model-scale Reynolds number, in the case of uniform inflow and non-cavitating conditions. The development of such advanced computational tools is required, especially in modern propeller design, where for reducing propeller-induced hull vibrations, efficiency decay and noise generation due to cavitation, there is a continuous trend towards an increased complexity of the blade geometry, primarily due to the low aspect ratio and to the skew of marine propellers, which cause strong three-dimensional effects. This complexity requires a better knowledge of the wake characteristics in terms of the mean field and turbulent quantities. Therefore, there is a rising interest on detailed data of the velocity flow field around the blades and in the wake, supporting the flow modeling and the validation of the computational tools. Starting since 1997 at INSEAN started a project aimed to obtain high quality data for CFD validation. Measurements of velocity fields, radiated pressure fields cavitation patterns were performed. The chosen propeller was the INSEAN E779a, propeller which was already investigated in the 80's by adopting phase sampling LDV techniques [1],[2].

The present Database was obtained by using LDV and 2D-PIV. Both techniques allow a powerful investigation of the flow field. LDV was used to perform the survey of the 3 velocity components in transversal planes, while PIV measurements were performed along longitudinal planes, acquiring the axial and the radial velocity components. All the measurements were performed in phase with propeller angular position. Furthermore recently radiated pressure fluctuation and cavitation pattern has been measured in order to validate Cavitation BEM calculations

Propeller geometry, velocity, pressure fluctuations and cavitation pattern data are available for downloading on Internet at http://crm.insean.it/E779A.

Propeller Model

The E779a is a four blade propeller (figure 1), Wageningen modified type, skewed, with a uniform pitch (pitch/diameter = 1.1), a forward rake angle of 4° 3" and a diameter of 227.2 mm. The propeller was designed at the end of the 50's for a twin-screw ferry but unfortunately no full-scale data are available. In the 60's the model propeller was chosen as reference propeller model of the Italian Navy Cavitation Tunnel (C.E.I.M.M.).

Propeller geometry is available as tables, dxf files, dwg files and Tecplot files (mesh generated for BEM computations).

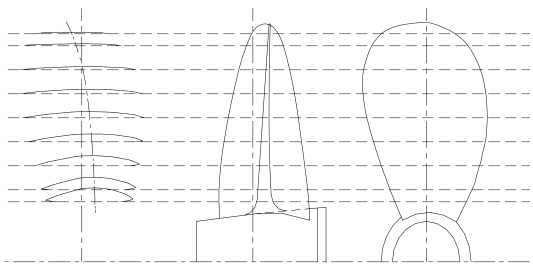

Figure 1: E779a propeller model.

Test facility and experimental setup

All the measurements were performed at the C.E.I.M.M. Tunnel. The test section is a square, closed jet type (0.6m×0.6m×2.6m). Perspex windows on the four walls enable the 90° optical access required for PIV. The nozzle contraction ratio is 5.96 and the maximum water speed is 12 m/s. The maximum free stream turbulence intensity in the test section is 2% in the regions behind the wake of the shaft supports, while it reduces to 0.6 % in the propeller blade inflow at a radial position equal to 0.7 R (R being the propeller radius). The flow uniformity of the axial and the vertical components is within 1%.

The propeller model is mounted on a front dynamometer shaft. This arrangement of the propeller and the length of the test section, which is about 15 times the propeller diameter, allows the slipstream to develop freely in the downstream direction as in a real operative condition. An encoder, with a resolution of 0.1°, mounted on the dynamometer shaft, feeds a special signal processor, which provides the angular position of the propeller to the LDV system and also generates the trigger signal required for synchronizing the propeller with the PIV system and the digital cameras

LDV measurements.

LDV measurements were performed at the advance coefficient J=0.88 and a five transversal planes located 2.15 diameters downstream from the propeller trailing edge. An example of the longitudinal evolution of the axial velocity is reported in figure 2. Main results reporting LDV measurements can be found in the references [3],[4],[5].

PIV measurements

PIV measurements were performed at 3 different loading conditions (J=0.702, 0.88, 1.02), in the wake region extending from the propeller leading edge to 2 diameters downstream. Measurements were performed for 19 angular positions (from 0 to 85° with 5° step). Mean flow fields and turbulence fields, in phase with the propeller, were obtained and reported in reference [8], [9]. An example of the velocity field obtained with PIV is reported in figure 3. A detailed comparison of PIV and LDV measurements is reported in the reference [10] (see figure 4)

Pressure fluctuation measurements

Inflow Pressure fluctuation measurements were performed with the main goal to point out the noise sources and to evaluate velocity-pressure correlations [12]

Cavitation Pattern measurements

Advanced image techniques were developed to obtain quantitative information on both the cavity extension and thickness. A detailed map of the cavitation pattern, over a wide range of the propeller working conditions, is established [11]. In figure 5, the extention of the cavity area at different loading condition and cavitation index , as example, is reported .

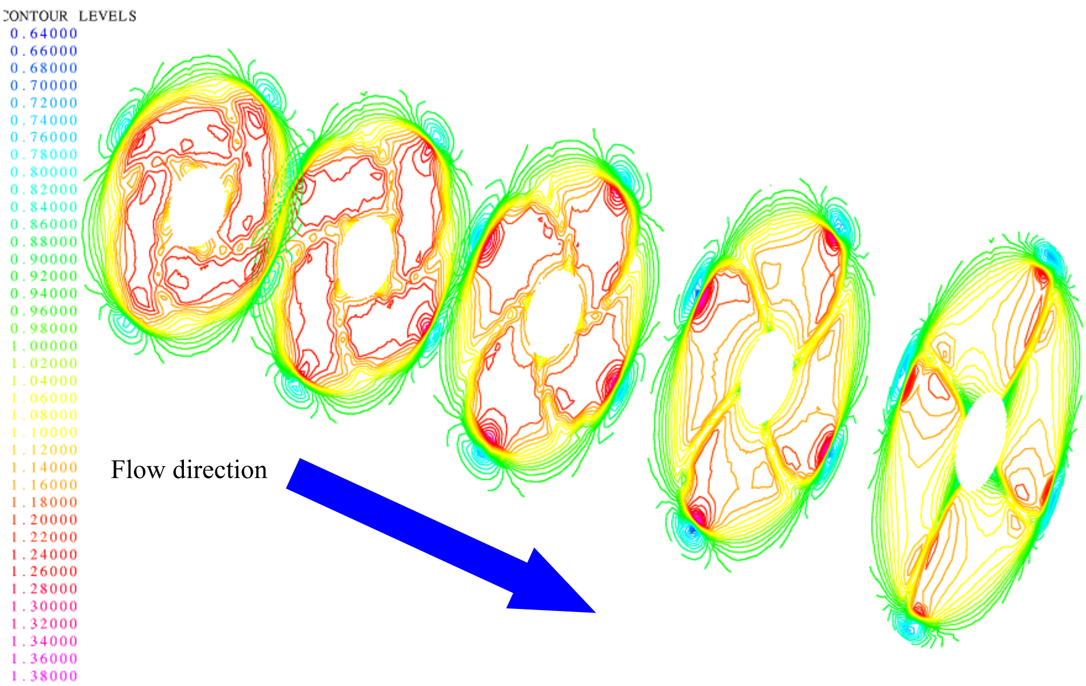

Figure 2: Longitudinal evolution of the axial velocity by LDV

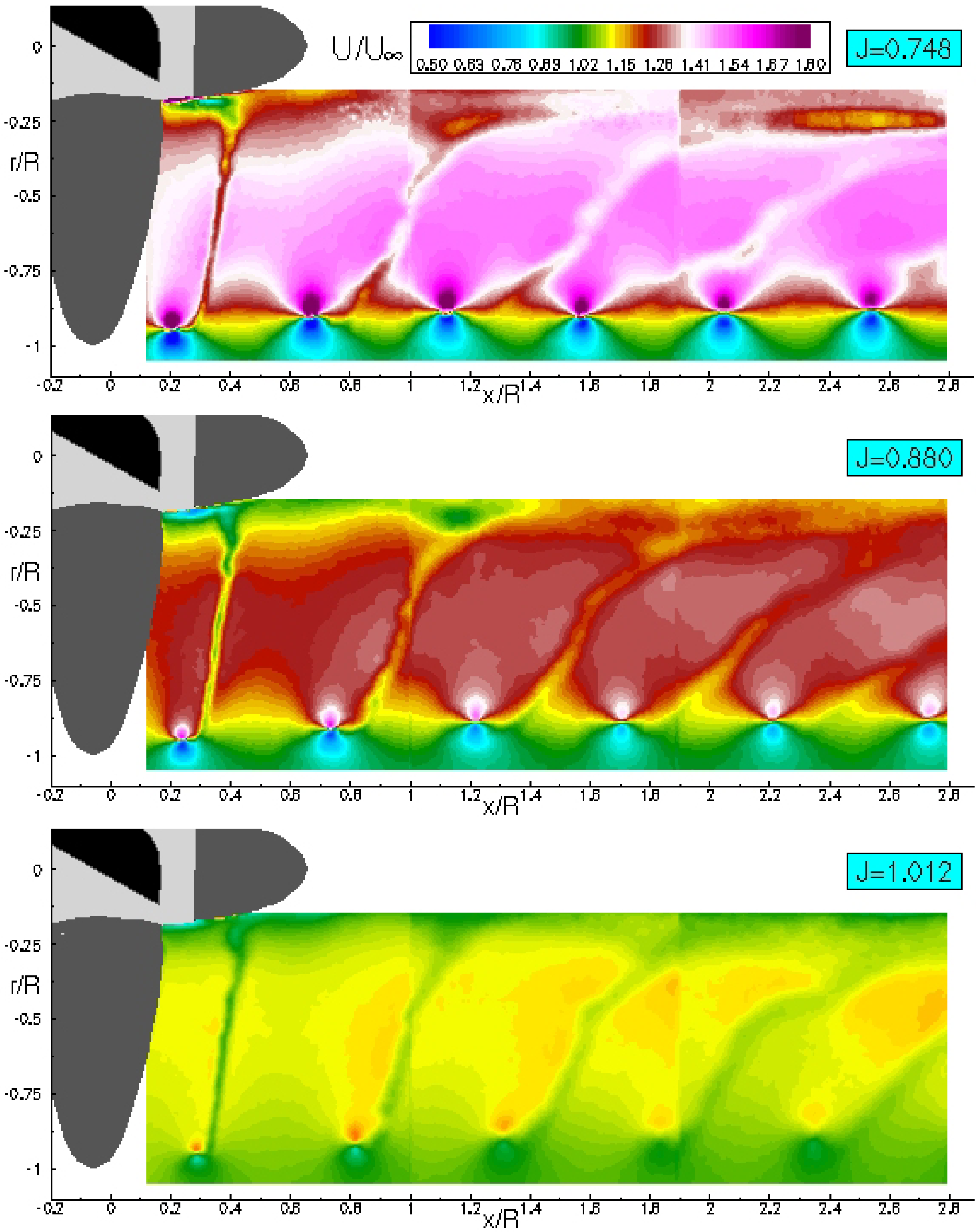

Figure 3: Longitudinal (U/U_∞) component distribution at different advance coefficient and for θ=0°.

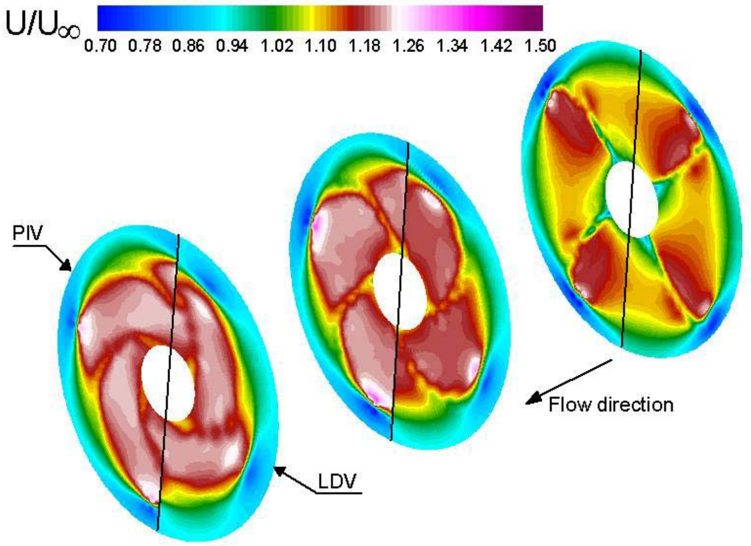

Figure 4: PIV and LDV Axial velocity comparison

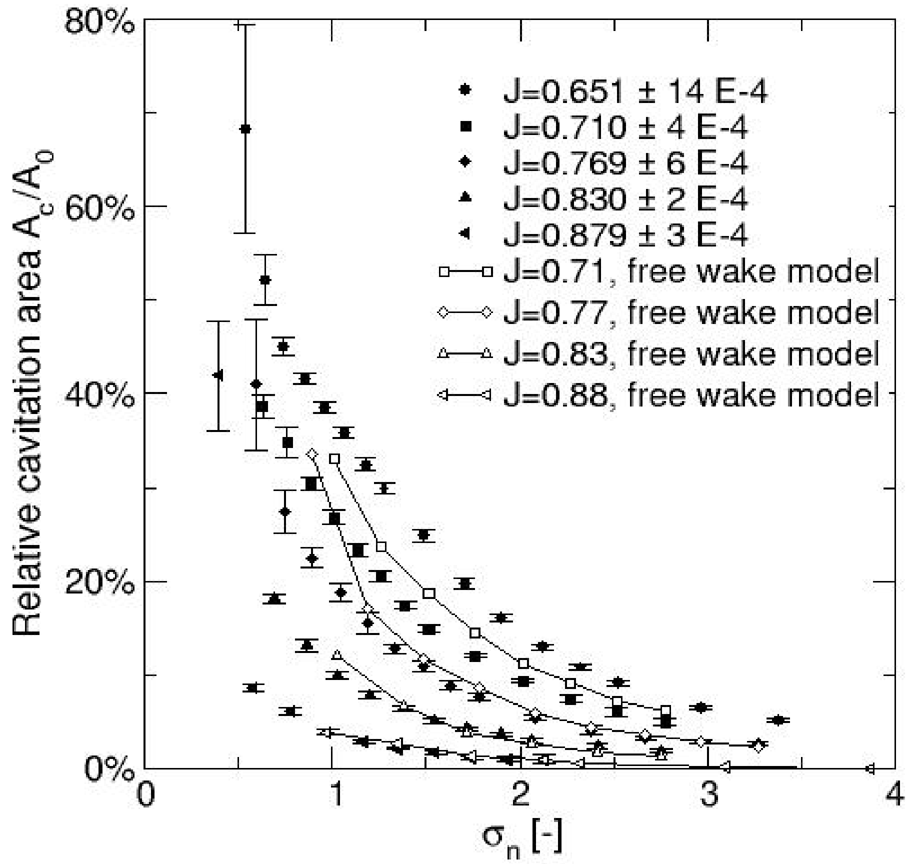

Figura 5: Cavitation extention at different loding and cavitation index

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