Interferometric Particle Imaging for cavitation nuclei characterization in cavitation tunnels and in the wake flow

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Introduction

Rudder and propeller cavitation causes vibrations, erosion and damages of the ship. Cavitation also impairs the vessel efficiency. Cavitation effects are influenced by water quality. One important parameter is the nuclei concentration. Therefore the objectives of KonKav include measurement of nuclei concentrations in cavitation tunnels and in the wake flow of a vessel. The University of Rostock developed a modified Interferometric Particle Imaging (IPI) technique to achieve this goal. Different measurements in model basins and full scale were performed.

Applied Techniques

The IPI measurement technique provides the required characterization of particle properties by light scattering [1] & [3]. The basic principle is to illuminate the particle by coherent light and record the scattered intensity distribution. A particle has number of glare points which depend on the particle structure. The particles are observed with a defocussed camera. By defocussing the observation plane an interference pattern of the glare point sources can be recorded. For a reliable concentration measurement in cavitation tunnels the IPI technique was adapted for the specific application. In cavitation processes bubbles interact as nuclei. Micro bubbles are expanded in low pressure regions and form cavitation structures. In the investigated applications a huge number of small solid particles in cavitation tunnels disturb measurements. Therefore spherical shaped bubbles were separated from solids by their IPI interference fringe system [4]. The recorded size of the defocused particle images depends on the aperture of the optics and the focal plane. An optimized focal plane for the IPI recording depends on the particle density in the flow and can be specified by the calculation of the sum over the derivatives (Laplace transform) of the images in a focal sequence. The result is a quality curve with three maxima for different specific focal points. The center maximum is the sharp focal point. The higher one of the other two maxima is the best focal point for IPI. For concentration measurement the individual particle images must be detected. For reducing the overlap and decreasing the complexity of the image processing only a laser beam without laser light sheet optics was used. Beside a simpler localization of the defocussed images the frame rate of the camera can be increased, because only an elongated rectangular ROI can be used. For particle detection a correlation of the frames with a template image in aperture shape is used. The correct size of the template is searched iterative. The maximum of the correlation function provides the position for each particle in the frame. The reduced pixel number and the simpler image processing allow continuously real time IPI measurements. One-dimensional Fourier transforms are applied to each line of the detected particle images. In case of the homogenous spherical particle the local maximum in the PSD yields the fringe count and so the particle size. The particle size is proportional to the fringe count by a factor coming from Mie calculations [3] & [4] for the specific experimental setup. Because of the large amount of solid particles in the flow, the bubble images with clear periodic fringes must be separated from speckle dominated or rotated images. This classification in bubbles and solids is also based on Fourier analysis. The spectra from the Fourier analysis contain more information than only the particle size. The PSD has exact three local maxima in case of a bubble and in case of a solid particle more frequencies occurs [4]. The mean intensity of the particle image is a measure for the particle position in the laser beam according to its size class [3]. Small particles scatter less light and are therefore less intense than larger particles. Model based curves are fitted to obtain the relevant parameters. Two methods are investigated to achieve a solution to this issue.

Results & Conclusion

First real time experiments with an industrial camera and a DPSS laser were successful. During the test the IPI analysis algorithm achieved up to the 6 frames per second. Successful measurements have shown that our modifications/simplifications of the Interferometric Particle Imaging technique allow its utilization for particle characteristics analysis in the wake flows of a ferry ship and also in model basins and cavitation tunnels. For further details see the full paper.

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