Image-Based Measurement and Methodology of Evaluating and Calibrating Cavitation Models for Marine Propeller Flows

Yi-Chih Chow, Yaw-Huei Lee, Yu-Chi Chang

Department of Systems Engineering & Naval Architecture, National Taiwan Ocean University, Keelung, Taiwan

Ching-Chin Tu, Ship and Ocean Industries R&D Center, New Taipei City, Taiwan

Long Abstract

Introduction

Cavitation can be generated by marine propellers due to their operational conditions combined with factors of blade design. In order to design a propeller having high efficiency and long life cycle, the characteristics of cavitation (especially the occurrences and the locations of cavitation on a propeller blade surface) associated with a specific propeller design must be understood to certain degree.

To simulate cavitating propeller flows, RANS coupled with cavitation models can be used to yield feasible results even with increased flow complexity due to cavitation [1][2]. However, it is well known that the results of RANS simulations are sensitive to the cavitation and turbulence models chosen. Therefore, the predictability of RANS needs to be validated with experimental data at least in some benchmark tests in order for RANS to be accepted or calibrated to become an effective design tool.

In order to provide an objective and informative comparison for numerical results, the experimental data should be acquired and analyzed in such a way that the occurrences and the locations of cavitation can be quantified. Salvatore et al. [3] presented the results of the VIRTUE 2008 Rome Workshop, where six RANS codes (with different cavitation and turbulence models), one LES (Large Eddy Simulation) code and one BEM (Boundary Element Method) code computed the flow case of a propeller whose experimental results of cavitation were acquired by Pereira et al. [4]. They analyzed their phase-locked images of cavitation using the cross-correlation method to identify the extension of sheet cavity on the propeller surface. Due to the fact that their cavitation patterns are quite regular and steady, i.e., the shape and range of the cavitation area is almost fixed from image to image, one may easily quantify the differences between the experimental and the numerical results of this case. It is clearly evident that once the cavitation phenomena encountered are unsteady and complex, one needs to develop a methodology to quantify the occurrences and the extensions of cavitation in order for the numerical results to be compared in a meaningful way. This presentation will describe an image-based measurement and methodology for this purpose just mentioned.

1. Methods

The problem we specifically deal with here is unsteady cavitation occurrences on a marine propeller surface, and we focuse on the evaluation and calibration of a specific cavitation model built in the commercial CFD code FLUENT and developed by Singhal et al. [5]. Using the phase-locked imaging technique (as shown in Fig. 1(a)), and processing and analyzing the images acquired (as shown in Fig. 1(b)), the spatial distribution of the probability for the occurrence of cavitation (cavitation occurrence probability, COP) on the propeller blade can be obtained (as shown in Fig. 1(c)). We will show that the COP is equivalent to the vapor volume fraction (VVF) computed in a RANS simulation. As a result, a meaningful, quantitative comparison between the experimental and the numerical results can be established, and further evaluation and calibration of the model can be achieved. It is expected that this measurement and methodology highlight the modeling issues and the possible remedies.

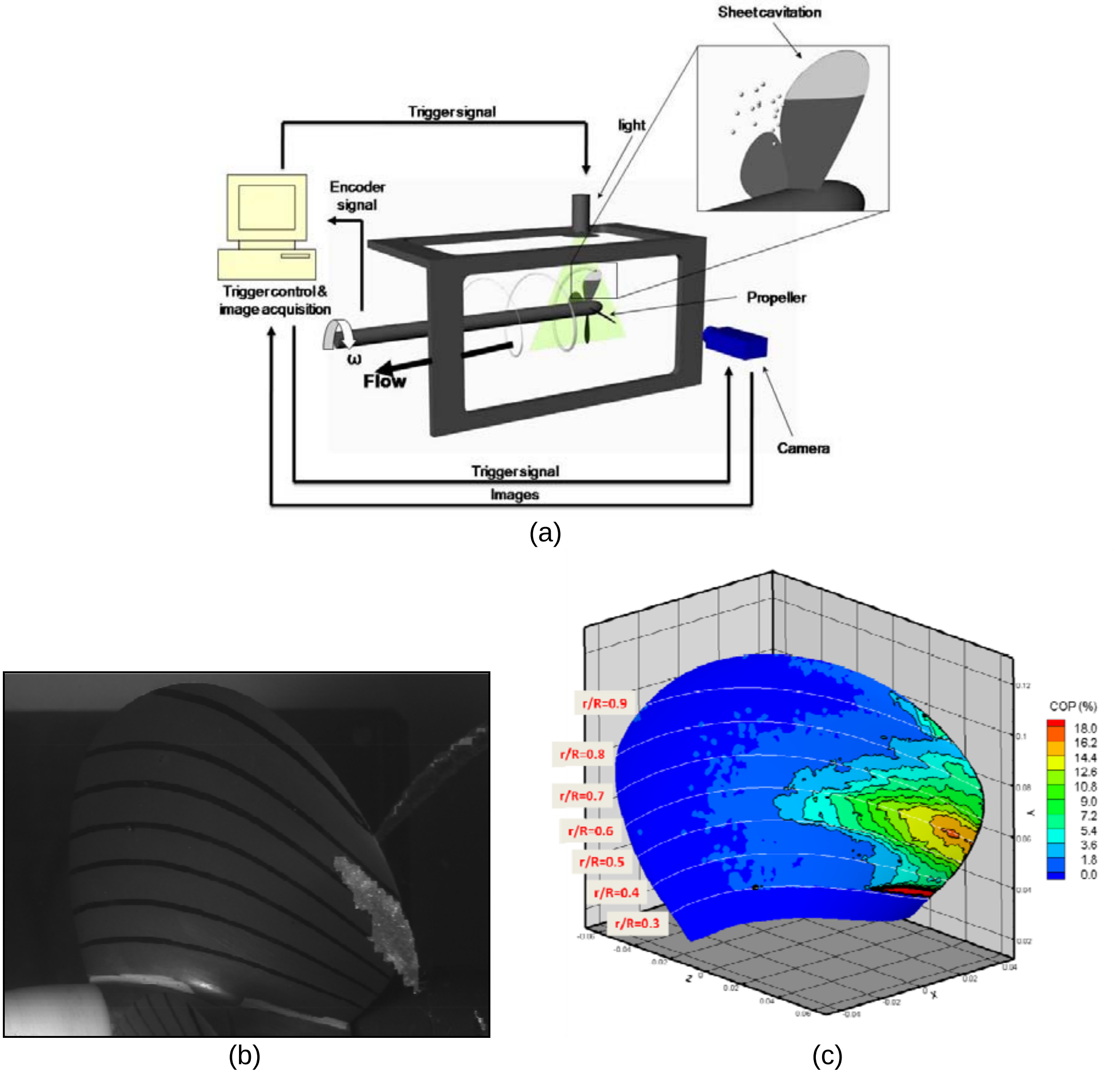

Figure 1. (a) Schematic of the experimental setup, (b) sample of a processed and analyzed image, and (c) the experimental COP distribution

References

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