NUMERICAL SIMULATION OF HULL PRESSURE FLUCTUATION INDUCED BY PROPELLER CAVITATION USING OPENFOAM

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Keywords: *pressure fluctuation, propeller cavitation, OpenFOAM*

1. Introduction

The propeller cavitation, one important aspect of propeller performance, has been studied by experimental and numerical approaches. The commercial CFD software, such as ANSYS FLUENT, STARCCM+, have been widely used to study the propeller cavitation. Da-Qing Li (2012) has predicted the E779A cavitation in non-uniform wake based on RANS approach and Zwart cavitation model using ANSYS FLUENT. Kwang-Jun Paik (2013) has predicted the propeller cavitation pattern and the hull pressure fluctuation induced, using FLUENT and SchnerrSauer cavitation model.

Recently, OpenFOAM, the open-source CFD platform, has been increasingly popular in the numerical simulation of propeller cavitation. Abolfazl (2015) has predicted the PPTC propeller cavity extent within a 12°inclination of shaft using ILES method and SchnerrSauer cavitation model based on OpenFOAM. Rickard E Bensow (2015) has studied the cavity extent, flow field and forces on the propeller of a 7000 DWT chemical tanker, with ILES method and Kunz cavitation model adopted in OpenFOAM. Zheng Chaosheng (2016, 2017) has predicted the unsteady propeller cavitation and hull pressure fluctuation induced in the ship stern using RANS method and OpenFOAM, the cavitation shape and the first blade frequency (1BF) amplitudes of hull pressure fluctuation predicted resemble well with the experiment observations and measurements.

The present work aims to predict the unsteady propeller cavitation in the stern region of a 14000 TEU container vessel, with special attention to the mesh independency on the unsteady cavitation behavior and hull pressure fluctuation.

2. Numerical methods

The unsteady viscous RANS approach and SchnerrSauer cavitation model are adopted to simulate the unsteady propeller cavitation. The SST $\kappa\omega$ turbulence model is chosen to solve the turbulent viscosity, and the free surface is neglected. The computation domain is divided into two sub-regions, the ship region and propeller region, all consist of hexahedral cells generated using HEXPRESS, and the interpolation between the non-conforming interfaces of the two sub regions is accomplished by AMI, implemented in OpenFOAM.

To improve the convergence, the full wetted flow is simulated to obtain a quasi-stable flow field using MRF method, then sliding mesh is applied to mimic the rotation of propeller, and the cavitation model is activated to simulate the unsteady propeller cavitation. The scotch decomposition method is adopted for parallel computations.

3. Results and Discussions

The numerical simulation condition is summarized in Table 1.

Table 1: The numerical simulation condition

n	28rps
$\sigma n_{0.8R}$	0.2493
KT	0.1887

In order to investigate the mesh independency, three grid sizes, the coarse, medium and fine mesh are used, as shown in Table 2 and Figure 1.

Table 2: The coarse, medium and fine mesh

	Coarse	Medium	Fine
Number of cells in ship region	3253362	5516333	9783416
Number of cells in pro region	652032	1017692	1585578
Total number of cells	3905394	6534025	11368994

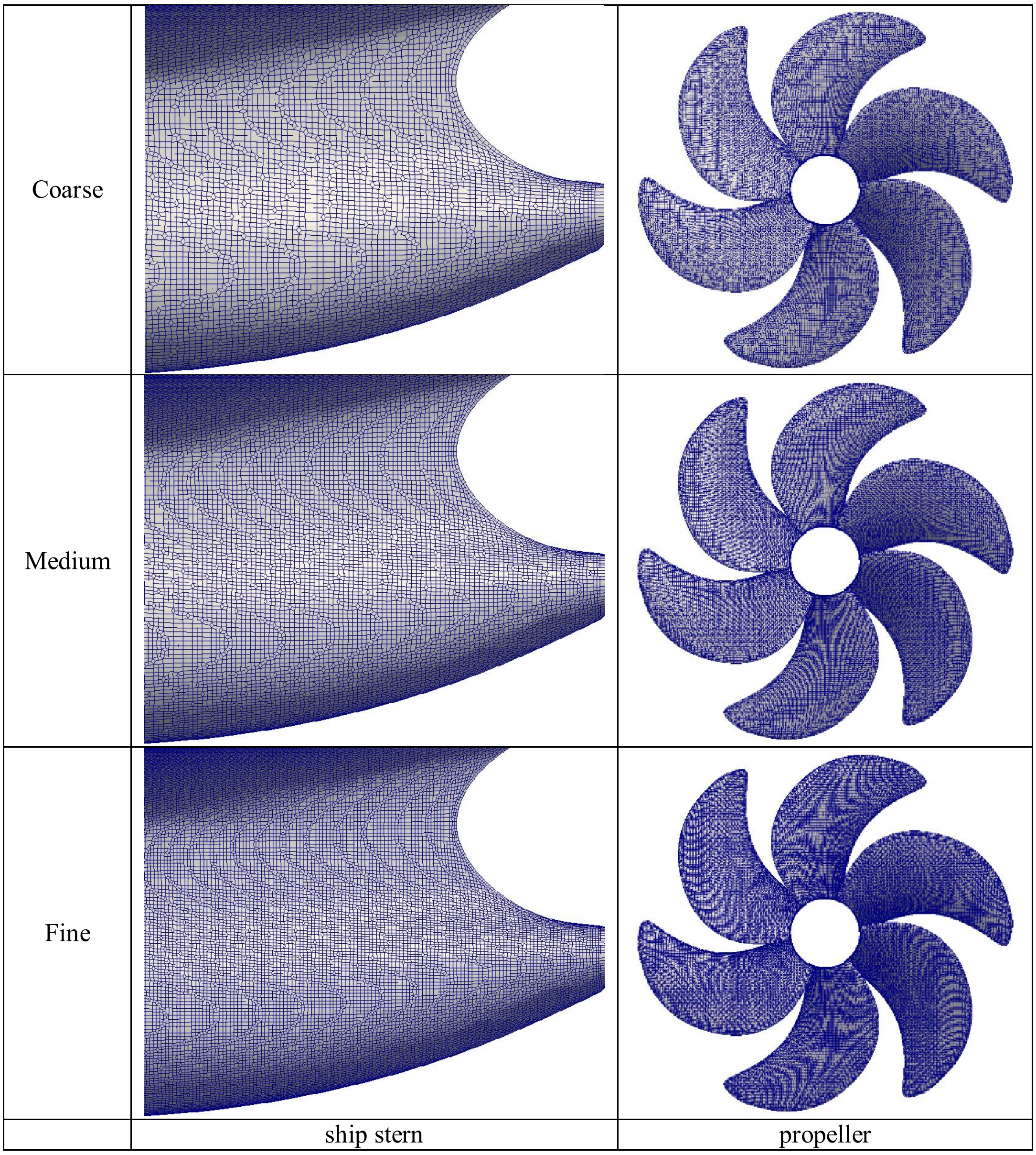

Figure 1: The surface mesh of ship stern and propeller

In the study, 300 CPU cores are utilized in the numerical simulation, and the time cost for the unsteady cavitation prediction in the coarse, medium and fine mesh is recorded in Table 3.

Table 3: The time cost for the unsteady cavitation simulation

	Coarse	Medium	Fine
Time (hours)	2.86	5.26	10.53

The predicted cavitation in the stern region is compared with the experiment sketches side-by-side in Figure 2. The predicted cavity, represented by vapour iso-surface of 0.1 shows the same behaviour as the experiment observations. The key feature, the extent change of the attached cavity with the rotation angles correlates well with the experiment, e.g. the cavity begins at about the same location $\varphi \approx -10°$, reaches the maximum area at $\varphi \approx 20°$(the rotation angle φ is defined as 0° at 12 o' clock).

In Figure 2, compared with the coarse mesh, the attached cavity predicted of the medium mesh seems closer to the outer radius, which is more accordant with the experiment observation. While, the cavity shows little difference between the medium and fine mesh. Taking the cost time into account, it implies that the medium mesh can meet the accuracy requirements of the unsteady propeller cavitation.

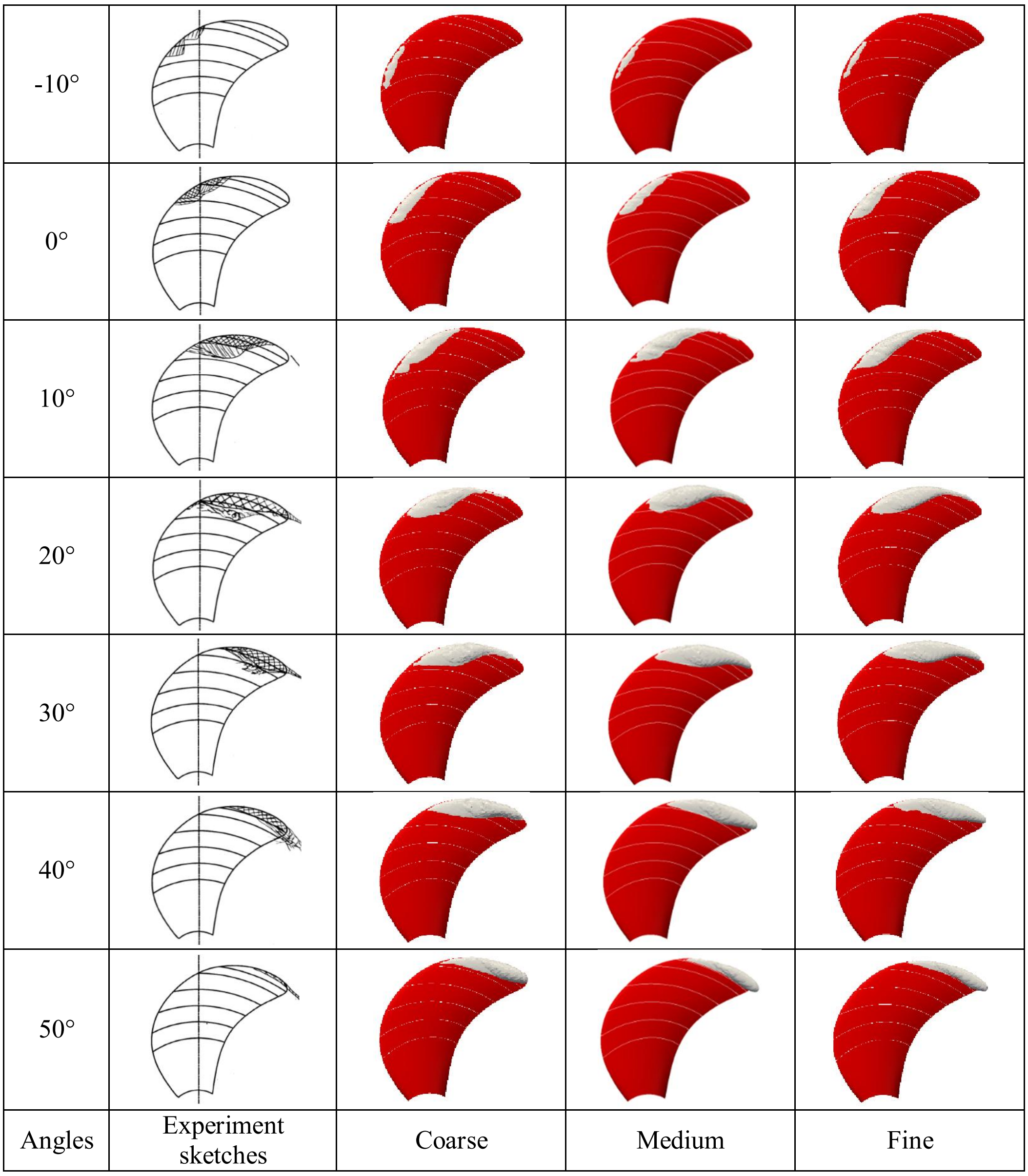

Figure 2: The experiment sketches vs. prediction

As to the hull pressure fluctuation induced by propeller cavitation, the monitor points are arranged on the stern surface shown in Figure 3. The pressure fluctuation predicted is compared with the experiment in Figure 4.

In Figure 4, the 1BF (1st Blade Frequency) amplitudes of hull pressure fluctuation predicted of the coarse mesh has a significant gap with the experiment, which is mainly due to the high numerical dissipation across the coarse mesh. The medium mesh obtains a dramatic improvement. The fine mesh gives more accurate results in principle, nevertheless the advancement is not as obvious as the one between the coarse and medium mesh. As a whole, it also indicates that the medium mesh can obtain more satisfactory time efficiency and precision of the hull pressure fluctuation.

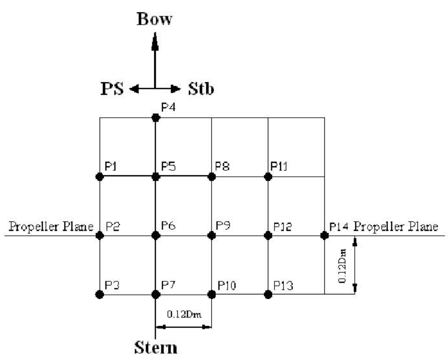

Figure 3: The arrangement of monitor points

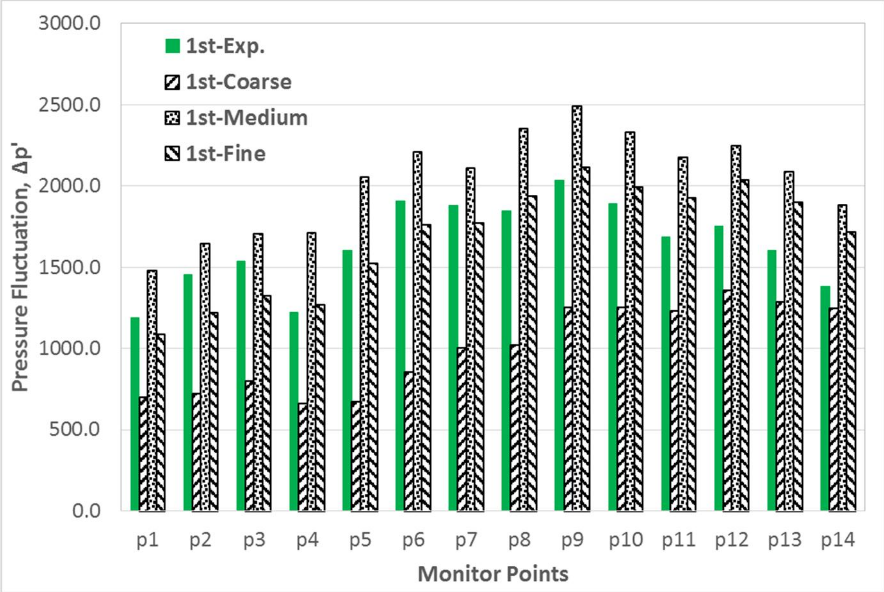

Figure 4: The 1BF of hull pressure fluctuation predicted vs. the experiment

4. Conclusions

The propeller cavitation shape and the amplitudes of the first blade frequency (1BF) of the hull pressure fluctuation predicted resemble well with the experiment observations and measurements, and the results also shows that the medium mesh can obtain more satisfactory efficiency and precision of unsteady cavitation behaviour as well as the hull pressure fluctuation.

Acknowledgements

This work is financially supported by National Natural Science Foundation of China (Project NO. 11332009).

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