Prediction of Hydrodynamic Propeller Loads for Strength Evaluation using CFD

Hyeonji Kang, Maritime Research Institute, Hyundai Heavy Industries Co., Ltd., Seoul, Korea
Jaewook Hur, Maritime Research Institute, Hyundai Heavy Industries Co., Ltd., Seoul, Korea
Hyoungsuk Lee, Maritime Research Institute, Hyundai Heavy Industries Co., Ltd., Seoul, Korea

Long Abstract

Introduction

Numerical prediction based on computational fluid dynamics (CFD) for hydrodynamic loads on blade has been studied by many researchers [1][2]. Verma et al. (2011) evaluated the possibility of Large Eddy Simulation (LES) application for prediction of hull effects. They noted that the vortex structure including vortex core location was affected by the presence of hull [3]. Hur et al. (2011) studied the quasi-steady analysis for crash stop astern condition. They suggested that the structural analysis of the propeller at initial design stage was evaluated with steady analysis at full astern condition [4].
This paper presents the numerical prediction of hydrodynamic loads on blade for various operational conditions including crash stop astern condition. The strength evaluation is also conducted using calculated hydrodynamic loads for structural safety survey in the initial design stage.

1. Methods

In general, the potential analysis has been used to predict the hydrodynamic loads; however the potential analysis is difficult to accurately consider the hull-propeller interaction and furthermore cannot be applied at crash stop astern condition. During the crash stop astern, the propeller rotates reversely while the vessel moves in the forward direction, therefore the induced flow by the propeller is in the opposite direction of the inflow. Due to the strong interaction between both flows, the large vortex ring is generated. (Figure 1)

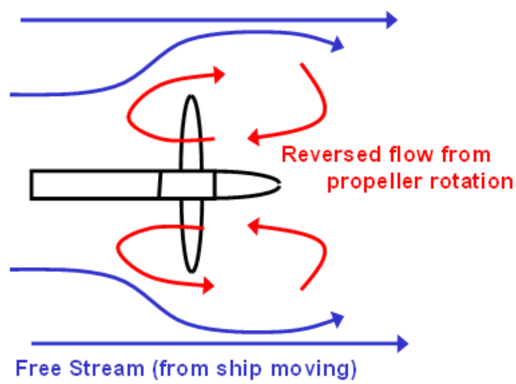
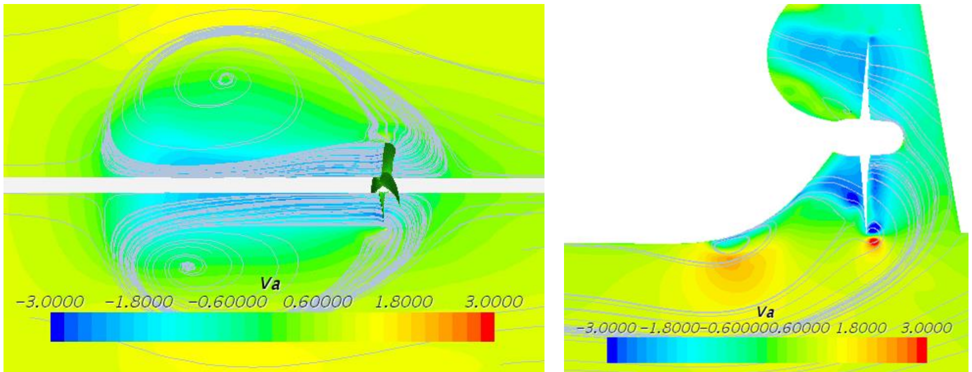


Figure 1. Schematic of crashback condition (Verma, 2011)

The result of the CFD analysis was verified with self-propulsion test results in the sea trials of large commercial vessel (LPG carrier) for the ahead condition. Based on the verified methodology, the hydrodynamic loads for the astern condition are predicted by using CFD code considering hull and rudder. The calculated torque at astern condition was also compared with sea trial results.

2. Results and Summary

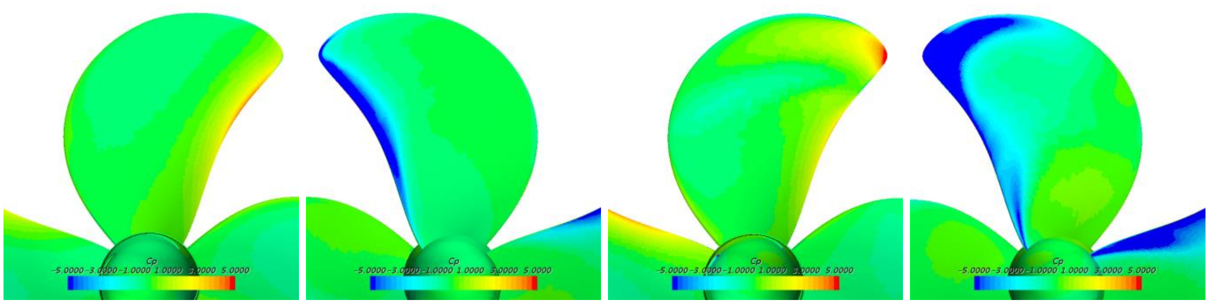
Figure 2 shows the flow pattern with velocity distribution and streamlines around propeller at astern with and without hull. The large vortex ring is generated due to opposite flow direction. The presence of the hull makes the difference in the flow pattern. Remarkable difference between the two results is the vortex structure around hull and propeller.



(a) (b)

Figure 2. Velocity distribution (normal direction) with streamlines at astern condition (a) w/o hull (b) w/ hull

Figure 3 (a), (b) show pressure distributions on the blade with the hull for zero degree and 180 degree, respectively. The hull plays a role of blockage in front of propeller. The aft hull form is different from axisymmetric geometry for up and down direction such as torpedo or submarine. For this reasons, the blockage effect of the hull is different according to blade position. At zero degree position, the level of pressure on the blade is lower than at 180 degree position.
Based on this study, CFD methodology is suggested to evaluate the structural safety of the propeller blade in the initial design stage.



(a) (b) (c) (d)

Figure 3. Pressure distribution in the presence of hull on (a) suction side (b) pressure side (at 0 degree) (c) suction side (d) pressure side (at 180 degree)

References

[1] H. Jang and K. Mahesh. Large eddy simulation of marine propulsors in crashback. 28th Symposium on Naval Hydrodynamic, 2010

[2] H. Jang and K. Mahesh. Large eddy simulation offlow around a reverse rotating propeller. Journal of Fluid Mechanics, 729:151-179, 2013.

[3] A. Verma, H. Jang and K. Mahesh. Large eddy simulation of the effect of hull on marine propulsors in crashback. 2nd International Symposium on Marine Propulsors, 2011

[4] J. W. Hur, H. Lee and B. J. Chang. Propeller loads of large commercial vessels at crash stop. 2nd International Symposium on Marine Propulsors, 2011