ABSTRACT

In order to investigate the characteristics of fluid-structure interaction (FSI) of the hydrofoil, the bi-directional FSI numerical method was developed. Based on the ANSYS software, the Large Eddy Simulation (LES) method and Finite Element Method (FEM) are combined to realize the iterative solution of fluid and structural domain. The results of vibration and pressure with and without FSI effect are compared. It is shown that when considering the FSI effect, the hydrofoil will oscillate periodically. Even if the vibration amplitude of the hydrofoil is small, it will cause the unsteady pressure fluctuation of the flow field.

KEY WORDS: Fluid-structure interaction; hydrodynamic; vibration; hydrofoil; computational structural mechanics (CSM).

INTRODUCTION

As the development of the ship industry, the higher performance of hydrodynamic and noise of propeller is needed. In the past, the propeller is considered rigidly during the design and the interaction between propeller and fluid is ignored. In the recent years, it is found that the interaction between propeller and fluid has much influence on the unsteady pressure in the near field and noise, so in order to designing high performance propeller the interaction between propeller and fluid can’t be ignored. The fluid-structure interaction effects must be considered.

The fluid structure interaction between metal structure and fluid has been studied many years in the aspect of aerodynamic. The aeroelasticity of the turbomachinery blade is studied by coupled Fluid-structure simulation (Sadeghi and Liu, 2005). A flow solver is coupled to a structural solver by use of a fluid-structure interface method. The integration of the three-dimensional unsteady Navier-Stokes equations is performed in the time domain, simultaneously to the integration of a modal three-dimensional structural model. The fluid structure interaction simulations of turbomachinery blade are studied widely (Carstens et al, 2003. Dettmer and Peric, 2006).

In the aspect of underwater, the studies of fluid structure interaction are mainly forced on the flexible material. Flow-induced oscillations of a single-bladed, single-stage sewage water pump were investigated by Benra (2006) using a one-way coupling method in commercial software and data exchanged was performed via output file at interface surfaces. A coupled boundary element (BEM) and finite element (FEM) approach is developed to study the fluid-structure interaction of flexible composite propellers in subcavitating and cavitating flows (Young, 2008; Akcabay and Young, 2014). It is found that the area of the high pressure is reduced and the distribution of stress is changed when the blade is deforming. Campbell and Paterson (2011) developed and validated fluid structure interactions of an expandable impeller pump using OpenFOAM and the developed a structural solver. The commercial software is used to study the fluid-structure interaction: ANSYS CFX for fluid dynamics and ANSYS Mechanical for structural mechanics with the ANSYS MFX solver to couple both program (Schildhauer and Spille-Kohoff, 2014). The results are compared with the Turek benchmark and have good agreement. It shows the capabilities of the commercial software to solve the fluid-structure interaction problem (Hu et al, 2013. Jitendra and Frank-Hendrik, 2015. AN et al, 2017). Actually in the water, the metal propeller is easy to couple with fluid and the resonances are created (Lou and Ji, 2019). But the influence of unsteady small displacement of the metal propeller to the fluid is not very clear now. It is necessary to study the fluid structure interaction between metal propeller and fluid.

The objective of this work is to develop a bi-directional FSI method to predict the hydro-elastic performance of the metal hydrofoil and study the effect of small deformation to flow field. In the paper, first the coupling method is introduced detailed. Then, the mesh, boundary condition and setup of the case are introduced. Finally the results are analyzed.

NUMERICAL APPROACH

In order to realize the solution of the fluid domain and structural domain, the LES method is used to calculate the flow field and the FEM is used to solve the structural vibration of the hydrofoil. The system coupling module is used to exchange data between two solvers.