Unsteady Dynamics of Cloud Cavitation on a Hydrofoil with Large Eddy Simulation
Ze Xiong  Ziru Li *  Keqiang Chen
School of Transportation, Wuhan University of Technology
Wuhan, Hubei, China

ABSTRACT

Cavitation erosion can often be related to the strong unsteady characteristics of cloud cavitation. The current study focuses on the capability of LES to predict the unsteady behavior of the cavitating flow around a NACA0015 hydrofoil. The Large Eddy Simulation (LES) results can reproduce more unsteady phenomena than the unsteady Reynolds-Averaged Navier-Stokes (URANS) results, and can predict closer location of cavitation closure, resulting in more accurate Reynolds-Averaged Navier-Stokes (URANS) results, and can predict closer location of cavitation closure, resulting in more accurate results can reproduce more unsteady phenomena than the unsteady flow around a NACA0015 hydrofoil. The Large Eddy Simulation (LES) capability of LES to predict the unsteady behavior of the cavitating characteristics of cloud cavitation. The current study focuses on the Curtiss erosion can often be related to the strong unsteady characteristics of cloud cavitation. Therefore, the evolution and the unsteady dynamics of the cavitating flow research field.

KEY WORDS: Unsteady cavitation; cloud cavitation; LES; re-entrant jet; cavitation erosion.

INTRODUCTION

Cavitation is a complex multiphase flow that often occurs in fluid flow systems where the local fluid pressure drops to a certain critical pressure (often taken as the vapor pressure of the fluid) (Frederick and Hammitt, 1980). It was first recognized in marine engineering by its negative effect on a newly built destroyer, Great Britain’s HMS Daring, resulting in unexpected poor power performance. The cavitation phenomenon often involves complex hydrodynamic and mechanical mechanisms, and even thermal and illuminative effects. It generally occurs in fluid engineering systems such as marine propulsion systems, rudder system and hydraulic turbines.

According to the typical shapes, cavitation phenomenon can be divided into the following types: bubble cavitation, sheet cavitation, cloud cavitation and supercavitation (Wang et al., 2001). The observed cavitation phenomena in the marine propulsion system and other hydraulic machinery often bring negative effects. Cavitation induced noise and vibration have significant influences on the safety of engines and vessels, and will bring huge threat to the stealth of navy vessels. In particular, cavitation erosion is one of the most harmful consequence, and can often be related to the strong unsteady characteristics of cloud cavitation. Therefore, the evolution and the unsteady dynamics of the cloud cavitation over the hydrofoil have been a hot topic in the cavitation flow research field.

With lots of experimental research of the unsteady cloud cavitation, it has been pointed out that the re-entrant jet can be attributed to be one of the main factors causing the shed of cloud cavitation from a partial sheet cavity (Kubota et al., 1992; Kawanami et al., 1997; Leroux et al., 2004). With the re-entrant jet into the internal cavity, massive cavitation cloud began to fall off. Foeth and van Terwisga (2006) applied the time resolved PIV to study the fully developed sheet cavitation on a hydrofoil with a spanwise varying angle of attack. For the PIV measurement, it has been described the process of periodic shedding of cloud cavitation more clearly. Huang et al. (2013) used a high-speed video camera to display the flow structures of cavitation, and a particle image velocimetry (PIV) technique to measure the time-averaged and instantaneous velocity and vorticity fields. The cloud cavitation shedding and its collapse lead to a wide range of flow speed pulsation around hydrofoil tail.

In recent years, with the gradual improvement of the computer technology, the numerical simulation of cavitation by CFD method is developed with an increasing concern. However, it is critical to use a suitable turbulence model for the capture of the unsteady dynamics of cloud cavitation and the prediction of shedding frequency and pressure fluctuations in the cavitating flow field. Li (2009) and Li (2010) explored the capability of unsteady Rayleigh-Averaged Navier-Stokes (URANS) method together with the SST k-ε turbulence model in the capture of unsteady dynamics of cavitating flows around a twist hydrofoil. It was found out that the standard SST k-ε turbulence model would overestimate the turbulent viscosity in the mixture region. Ji (2013) used the LES method to simulate the evolution of the cloud cavitation details. The wall-adapting local eddy-viscosity (WALE) model was used to give the Sub-Grid Scale (SGS) stress term, resulting in cavitation evolutions and shedding frequency which are in fair agreement with experimental results. Zhao et al. (2014) studied the sheet/cloud cavitating flow over a Clark-Y hydrofoil by the LES approach with a classical eddy viscosity subgrid-scale turbulence model. It is confirmed that the LES method are capable of capturing the initiation of the cavity, growth toward the trailing edge, and subsequent shedding with promising quantitative accuracy. The possibility for the assessment of cavitation erosion in an early stage of design is then greatly improved by the application of LES method.