Research on Unsteady Shear Layer Oscillation in 3D Open Cavity based on LES Method

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ABSTRACT

Cavity flows has widely application in different areas of engineering fields. The prediction of hydrodynamic characteristics in cavity flows, which relate to the safety of cavity flows, is one of the most key techniques in structural designing. In this paper, vortices structure in the process of shear layer oscillation in open cavity is captured by numerical simulation based on LES turbulent model. The present work focuses on calculating and analysis mechanism of vortices structure and shear layer oscillation in 3D open cavity, by using simple method to solve N-S equations with the finite-volume formulation, the calculating results show that a pair of vortex moves along flow direction, then climbing and breaking up instantaneously, and a big static vortex generates in the center of the open cavity as well as two small vortices generates at the top two corners of open cavity. The rules of pressure distribution of side wall and shear layer oscillation with different Reynolds number are gained in this paper, which can be applied to guide cavity strength-design.

KEY WORDS: Open cavity; Shear layers oscillation; LES; Vortices structure

INTRODUCTION

Cavity flows has extensive applications in different areas of engineering fields. One of examples is a suction-box reservoir in ships, bomb cabin in the aircrafts and gate slots in hydraulic structures as illustrated in Fig 1. Due to sudden change in structure surfaces flow may become separate at the corners and turbulent after that, which can cause severe shear layer oscillation. This can cause structural vibrations and noise, or even result in local structural destruction. Therefore studying the mechanics and hydrodynamic characteristics of shear layer oscillation of open cavity is of great significant.

On the issue of shear layer oscillation, there are mainly three methods to research. One is analytical solution; another is experimental investigation, there is also numerical simulation. Last century, in aspect of theory and experiments pointing at cavity flows, many researchers mainly focused on studying frequency and mathematical models of 2D shear layer oscillation by theoretical and experimental methods (Rossiter, 1964; He, et al., 2001; Yi, 1996; Chano, Payl K. 1970). The typical papers are published by Helmholtz and Rossiter. They pointed out the frequency chromatistics. Later other researchers started to explore more and begin to put in more time and efforts, and then they found some new areas of research such as instability of shear layer oscillation and resonance of flow and acoustics by experimental methods. Although Naudascher (1978) and other researchers vividly described the instability of shear layer oscillation, the mechanical problems are not given. From the acoustic point of view, He Z.Y. and Zhang M.M. (1995) researched the deflector plate’s influence on self-sustaining oscillation of circular cavity while acoustics characteristics were analyzed but vortices’ movement and flow character were neglected. Kuo C.H.& Jeng W.I. (2003) investigated the problem of shear layer oscillation of 2d rectangle cavity using laser slicing method in cycle waterways, then captured locking area of exciting cavity. D’yachenko, A.Yu., Terekhov V.I. and Yarygina N.I. (2008) investigated fluid induced oscillation of 2d cavity with angle then gave the rule of temperature changing and pressure distribution but neglected three dimension effect. Aiming at problem of shear layer oscillation, other researchers also gave different views, for instance, strong shear layer were not noticed (Ashcroft.C and Zhan.X, 2005; Grace.S.M.Dewar.W.G 2004) in the process of experimental research. While Rizzetta.DP (2003) and the similar conclusions were posed as

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