Available online at www.sciencedirect.com
ScienceDirect
Journal of Hydrodynamics
2011,23(4):466-475
DOI: 10.1016/S1001-6058(10)60137-0
www.sciencedirect.com/
science/journal/10016058

A PARTIALLY-AVERAGED NAVIER-STOKES MODEL FOR HILL AND CURVED DUCT FLOW*

MA Jia-mei, WANG Fu-jun, YU Xin, LIU Zhu-qing
College of Water Conservancy and Civil Engineering, China Agricultural University, Beijing 100083, China,
E-mail: jiameima@163.com

(Received January 22, 2011, Revised April 16, 2011)

Abstract: Turbulent flows past hill and curved ducts exist in many engineering applications. Simulations of the turbulent flow are carried out based on a newly developed technique, the Partially-Averaged Navier-Stokes (PANS) model, including separation, recirculation, reattachment, turbulent vortex mechanism. The focus is on how to accurately predict typical separating, reattaching and secondary motion at a reasonable computational expense. The effect of the parameter, the unresolved-to-total ratio of kinetic energy (f_k), is examined with a given unresolved-to-total ratio of dissipation (f_ε) for the hill flow with a much coarser grid system than required by the LES. An optimal value of f_k can be obtained to predict the separation and reattachment locations and for more accurate simulation of the resolved turbulence. In addition, the turbulent secondary motions are captured by a smaller f_k as compared with the RANS method with the same grid.

Key words: Partially-Averaged Navier-Stokes (PANS), flow separation, recirculation, reattachment, resolved turbulence

Introduction

The Reynolds-Averaged Navier-Stokes (RANS) equations are widely used for numerical predictions in engineering applications due to the low computational cost. However, it is found that the RANS is unsuitable for resolving fluctuating scales of motion[1]. The Large Eddy Simulation (LES) has the ability to accurately predict the resolved flow structures, but its application is limited because of too much computing cost[2,3]. Cheaper unsteady turbulent prediction methods are required for practical flow computations. Several hybrid methods that combine the best features of the RANS and the LES were developed, such as Detached Eddy Simulation (DES)[4], Very Large Eddy Simulation (VLES)[5], Partially Averaged Navier-Stokes (PANS) model[6-10].

The PANS model was developed recently based on the RANS $k-\varepsilon$ closure equations with various modeled-to resolved scale ratios[6,7]. Its equations vary smoothly from the RANS to the Direct Numerical Simulation (DNS) by two controllable parameters: the unresolved-to-total ratio of kinetic energy (f_k) and that of dissipation (f_ε)[6-8]. In this method, only the coefficients have to be changed depending on the choices of f_k and f_ε [11]. The PANS model was studied in some typical turbulent flows. Girimaji[7,8] applied the PANS model to the flow over a surface-mounted cube, the flow past a square cylinder and a turbulent square jet, and demonstrated that the PANS can capture the resolved turbulence. Basu et al.[12] used the PANS model to a cavity. Frendi et al.[13] compared three hybrid approaches (DES, URANS and PANS), and showed that the PANS model gives better results than the other two turbulence models for a turbulent flow over a backward facing step. Song and Park[14] focused their investigation on how to determine the control parameter f_k in the flow past a square cylinder.

In many engineering applications, the presence of a separating, reattaching and vortex flow causes an

* Project supported by the National Natural Science Foundation of China (Grant Nos. 51079152, 51079151).
Biography: MA Jia-mei (1982-), Female, Ph. D.
Crresponding author: WANG Fu-jun,
E-mail: wangfj@cau.edu.cn