Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 154 (2016) 420 – 425

Procedia Engineering

www.elsevier.com/locate/procedia

12th International Conference on Hydroinformatics, HIC 2016

Numerical Investigation of Backward Facing Step Flow over Various Step Angles

Hoi Hyun Choi[a], Van Thinh Nguyen[b]*, John Nguyen[c]

[a,b]*Dept. of Civil and Environmental Engineering, Seoul National University, 01 Gwanak-ro, Gwanak-gu, Seoul 151-744, South-Korea.*
[c]*John H. Daniels Faculty of Architecture, Landscape and Design, University of Toronto, Toronto, ON M5T 1R2, Canada*

Abstract

In this study, based on an open source CFD package OpenFOAM we carried out a number of numerical simulations using Reynolds Averaged Navier-Stokes (RANS) and Large Eddy Simulation (LES) approaches. The numerical investigation has been implemented for various step angles (10°, 15 °, 20 °, 25 °, 30 °, 45 °, and 90 °), different expansion ratios (1.48, 2.00 and 3.27), and Reynolds numbers (5000, 8000, 11000, 15000, 47000 and 64000). The comparisons of the flow structures, separation flows and reattachment lengths between the numerical results and the observations show very good agreement. The results obtained from LES show a better agreement with the observations than the results obtained from RANS model.

Peer-review under responsibility of the organizing committee of HIC 2016

Keywords: Computational Fluid Dynamics; Numerical analysis; Backward facing step; OpenFOAM; RANS; LES

1. Introduction

The study on the flow over a backward-facing step is very important in hydraulic structures and HVAC systems. The most important characteristics of such flows are the internal flows, flow separation and reattachment caused by sudden changes in cross-section geometries. Experimental study for 90° backward facing step flows was intensified for a wide range of Reynolds numbers and at different expansion ratios, such as Armaly et al. (1983), Ruck and

* Corresponding author. Tel.: +82-2-880-7355; fax: +82-2-873-2684.
E-mail address: vnguyen@snu.ac.kr

1877-7058
Peer-review under responsibility of the organizing committee of HIC 2016
doi:10.1016/j.proeng.2016.07.508

Makiola (1993), Lee and Mateescu (1998), Auburn et al. (2000), etc. A number of significant numerical studies of turbulent flows over 90^o backward facing step have been intensively carried out using Reynolds Averaged Navier-Stokes (RANS) Equations; e.g. Armaly et al. (2003), Nallasamy (1987), Speziale and Ngo (1988), Thangam and Speziale (1992), Lasher and Taulbee (1992). However there are still limited numerical results obtained from higher accuracy turbulence calculation methods, such as Large Eddy Simulation (LES), Direct Numerical Simulation; e.g. Le et al. (1997), Fureby (1999), Meri et al. (2000), etc., particularly DNS is mostly applied for a low-Reynolds number, and still very expensive.

Several experiments and numerical studies have been conducted for 90 degree step angle with different expansion ratios, however a detailed study on the turbulent structures, separation flows and reattachment lengths for various step angles is still not well documented. In this study, we have carried out a number of numerical simulations following the experimental cases of Ruck and Makiola for the geometry shown in Fig. 1, with various step angles (10^o, 15^o, 20^o, 25^o, 30^o, 45^o, and 90^o), different expansion ratios (1.48, 2.00 and 3.27), and Reynolds numbers (5000, 8000, 11000, 15000, 47000 and 64000), as shown in Table 1.

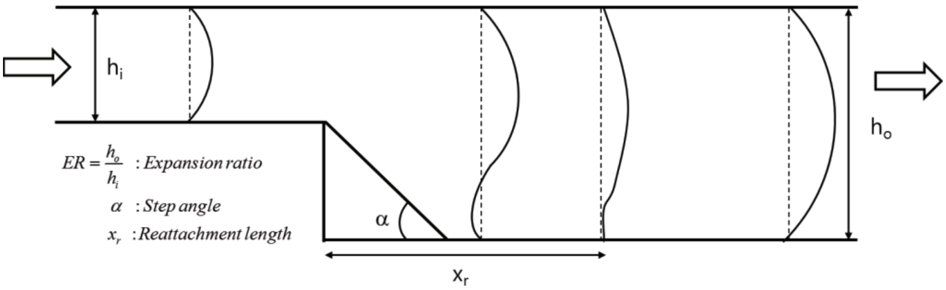

Fig. 1. Geometry of the experimental channel

Table 1. Parameters of Ruck & Makiola's experimental cases

Reynolds number	Expansion ratio	Step angle(α)
5000	1.48	10, 15, 20, 25, 30, 45, 90
8000	1.48	10, 15, 20, 25, 30, 90
11000	1.48	10, 15, 20, 25, 30, 90
15000	1.48	10, 15, 20, 25, 30, 45, 90
47000	1.48	10, 15, 20, 25, 30, 45, 90
64000	1.48	10, 15, 20, 25, 30, 90
15000	2.00	10, 15, 20, 25, 30, 45, 90
64000	2.00	10, 15, 20, 25, 45, 90
5000	3.27	15, 20, 25, 90
8000	3.27	15, 20, 25, 90
11000	3.27	15, 20, 25, 90
15000	3.27	15, 20, 25, 90

Nomenclature

ER	Expansion ratio
X_r	Reattachment length
α	Step angle
H	Step height