Aerospace Science and Technology 43 (2015) 199–212

Contents lists available at ScienceDirect

Aerospace Science and Technology

www.elsevier.com/locate/aescte

The evaluation of a detached eddy simulation based on the k–ω–$\overline{\upsilon^2}$–f model with three flow configurations

M. Mirzaei [a], A. Sohankar [b,*]

[a] Department of Mechanical Engineering, Yazd University, Yazd, Iran
[b] Department of Mechanical Engineering, Isfahan University of Technology, Isfahan, Iran

ARTICLE INFO

Article history:
Received 3 August 2014
Received in revised form 3 March 2015
Accepted 5 March 2015
Available online 9 March 2015

Keywords:
Detached Eddy Simulation (*DES*)
URANS
k–ω–$\overline{\upsilon^2}$–f
Large Eddy Simulation (*LES*)
Wavy channel
Side by side square cylinders

ABSTRACT

Detached Eddy Simulation (*DES*) based on the k–ω–$\overline{\upsilon^2}$–f model, termed *DES*–k–ω–$\overline{\upsilon^2}$–f, is developed and evaluated in the present study. In this model, the *RANS*–*LES* switching is achieved by an adaptation of the turbulent length scale between the *LES* and *RANS* regions. The *SGS* model coefficient is calibrated by the decaying homogeneous isotropic turbulence (*DHIT*). The capabilities of the proposed model are evaluated on various geometries, i.e. the plane channel flow, wavy channel flow and two side by side square cylinders. The *DES* results are compared with the *URANS* and *LES* results obtained in the present study and the available results obtained in other references. A good agreement is found between the results of the proposed *DES* model and the *LES* for three flow configurations employed. For the cases with flow separation, the *DES* model demonstrates accurate predictions in reproducing the resolved flow and turbulence quantities in comparison with full-resolved *LES*.

© 2015 Elsevier Masson SAS. All rights reserved.

1. Introduction

For many years, the Reynolds-averaged Navier–Stokes (*RANS*) models have been widely used to model various types of turbulent flows in industrial applications. The *RANS* models are dissipative and are hardly triggered into the unsteady mode, unless the flow instabilities are strong enough such as the flow around bluff bodies. The unsteady *RANS* models (*URANS*), although managing to resolve unsteady mean flows, fail to provide the proper flow physics for many cases with large turbulent structures. In Large Eddy Simulation (*LES*), the large turbulence scales are resolved, whereas the small ones i.e. smaller than the grid size, are modelled with a Sub-Grid Scale (*SGS*) model. It is proved that the resolution requirements near the walls impose a major challenge to the employing of *LES* for complex flows. By approaching toward the wall, even the large turbulent scales become small requiring a highly fine grid in the near-wall region.

Over the recent years, noticeable attention has been paid to the progress of hybrid modelling methodology as a combination of *RANS* and *LES* approaches. In these models, the *URANS* models performed in the near wall-region is combined with *LES* applied in the region away from the wall. Two typical methods have been used in the literature. In the first method, *LES* and *RANS* are coupled at a specific interface in the computational domain. The interface could be considered either pre-defined by choosing a grid line or a distance from the wall or solution-dependent keeping on adjusting with the flow. In this approach, equations of *LES* and *RANS* models are only valid in their layers, thus the modelled turbulence quantities (mostly the *RANS* and *SGS* viscosities) are directly forced being equal in the matching zone. This may cause a mismatch of the slope of the velocity profile between the *LES* and *RANS* layers [1,2]. In the second way, the coupling between the *LES* and *RANS* regions are performed by adaptation of the turbulent length scales, based on the same turbulence transport equations. The *URANS* and *LES* layers are matched by imposing a limit on the near-wall *RANS* length scale in the way that the outer layer of the near-wall *RANS* region is set by the *SGS* length scale. In this method, the switch between two models occurs automatically, so the user is free from the specification of the interface location.

A comprehensive review of various hybrid models and their applications are provided by Fröhlich and Terzi [3]. *DES* model was originally proposed by Spalart et al. [4] termed Detached Eddy Simulation (referred as *DES*–*SA*). *DES*–*SA* was based on one-equation Spalart–Allmaras model employing a transport equation for the eddy viscosity. In this model, depending on the wall distance, the length scale in the destruction term in replaced by

* Corresponding author.
E-mail addresses: m.mirzaei@stu.yazduni.ac.ir (M. Mirzaei), asohankar@cc.iut.ac.ir (A. Sohankar).

http://dx.doi.org/10.1016/j.ast.2015.03.002
1270-9638/© 2015 Elsevier Masson SAS. All rights reserved.