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2DV Nonlinear k-ε Turbulence Modeling of Stratified Flows

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Abstract

The commonly used linear k-ε turbulence model is shown to be incapable of accurate prediction of turbulent flows where non-isotropy is dominant. Two examples of non-isotropic flows which are due to stratification and consequently variation of density through vertical layers are saline water flow and the stratified flows due to temperature gradients which have a wide range of applications in marine waters. In this paper a nonlinear k-ε turbulence model firstly presented by Speziale [1] is implemented in the existing hydrodynamic model. The energy equation has been also added and solved in the hydrodynamic model. The hydrodynamic model solves the fully nonlinear Navier-Stokes equations based on an ALE (Arbitrary Lagrangian Eulerian) description. The model is an extension to WISE (Width Integrated Stratified Environments) 2DV numerical model, originally developed by Hejazi [2]. The simulated values have been compared with the experimental data and have shown acceptable agreements. The predictions are also compared with the results of the original model employing a standard buoyant k-ε turbulence model, which show the advantage of the new turbulence model in prediction of non-isotropic flows.

Introduction

Despite the intensive research efforts of the past decades to develop more general turbulence models, k-ε models still remain the most widely used approach by engineers and scientists for the solution of practical problems. The main advantage of k-ε turbulence models is due to the reasonable computational time compared with the more complicated models.

To improve the predictions of k-ε turbulence model a lot of research work has been carried out. Lumley [3] developed a turbulent constitutive relation which was based on the similarities between non-Newtonian fluids and nonlinear Reynolds stress and mean strain relation. Pope [4] presented a nonlinear k-ε turbulence model based on the Caley-Hamilton theorem and integrity basis tensors. An extensive research effort was carried by Speziale [1] to enable turbulence modeling with consideration of anisotropy by the application of nonlinear k-ε models. One example, where anisotropy is dominant and is widely applicable and important in geophysical, environmental and some other engineering turbulence flows, is stratified flow. The density variations due to stratification may be caused by heat transfer, salinity or other species concentration difference across the depth of flow. The flows which lie in this category may increase or damp turbulence fluctuations depending on occurrence of stable or unstable shear layers, which are widely