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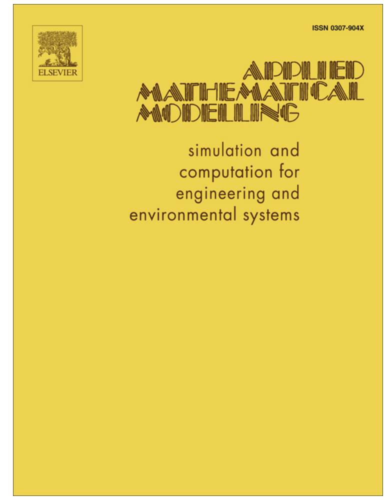

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Abstract

Large Eddy Simulation (LES) of turbulent channel flow with rib elements on bed is carried out using an extended version of Werner-Wengle (WW) wall model to investigate the roughness density and flow submergence effects on the flow features in depth as well as the validation of the applied model. Profiles of mean velocity, turbulence intensity, turbulent kinetic energy and turbulent production are compared with the related available experimental data. Inspection of the mean and fluctuating velocity profiles showed the capability of the used model to represent the turbulence structures and revealed that combined effect of roughness density and flow depth are important especially at shallow depth for larger pitch-to-height ratios.

Keywords: Open channel, Turbulent flow, roughness density, water submergence, LES

1. Introduction

Turbulent flows over rough beds are commonly encountered in engineering applications. For example, the cavitation damage in chutes and spillways will be actually decreased if individual roughness elements (normally with square sections) are installed as aerators [1]. So, many numerical and experimental simulations have been carried out by hydraulic engineers to understand the flow characteristics in the vicinity of roughness elements. Large Eddy Simulation (LES) is an accurate technique that is a topic of significant interest because of its ability to predict the flow details. Although, in general this technique is required high resolution to capture the small eddies but using proper wall functions one can perform LES on grids that do not resolve near wall layer [2].

Although the details of turbulent flow in the separation and reattachment zones are affected by the roughness geometry but the flow pattern can be divided into separated and recovery regions where a strong shear layer around the rough elements is developed. Fig. 1 depicts these regions. As it's shown in this Fig., separation zone starts from the separation point and extends toward the reattachment point on