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LARGE EDDY SIMULATION OF OPEN CHANNEL FLOWS WITH NON-SUBMERGED VEGETATION*

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Abstract: Results of several Large Eddy Simulations (LES) of open channel flows with non-submerged vegetation are presented in this article. It is shown that the vegetation can make the flow structure in the mainstream direction uniform for both supercritical and subcritical flows. For subcritical flows, the LES results of the ensemble-average of time-averaged velocity distributions at four vertical sections around a single plant are in good agreement with measurements. The velocity sees double peaks at the upper and lower positions of flows. For supercritical flows, the ensemble-average velocities see some discrepancy between LES and measurement results. Some secondary flow eddies appear near the single plant, and they just locate in the positions of the double peaks in stream-wise velocity profiles. It is also found that the vegetation drag coefficient deceases as the Froude number increases.

Key words: non-submerged, sub/supercritical flow, peak value, Large Eddy Simulation (LES), secondary flow, drag coefficient

Introduction

The presence of the aquatic and riparian vegetation in rivers can change the structure of the flow in the rivers. Additional drag forces may be generated by the vegetation, which in turn influence the velocity profiles and reduce significantly the mean flow velocity.

The effects of non-submerged vegetations on flow structures were extensively studied by flume experiments or mathematical simulations[1-5]. Zhang and Su[6] found that the vegetation plays a remarkable role in flow resistance even though the density of vegetation is low. Hui et al.[7] conducted experiments to investigate the effects of the vegetation diameter and flexibility on the drag coefficient. They found that the drag coefficient is nearly constant when the ecological factors are kept little changed. The additional flow resistance caused by the vegetation depends on the vegetation density and the types of vegetation[8]. Stone and Shen[9] designed a representative map of velocity distribution in an open channel flow with rigid vegetations in some experiments of open- channel flow with vegetation. The vertical time averaged velocity distribution does not follow the logarithm law because of the influence of vegetations, and the drag force coefficient increases with the increase of the relative water depth and Reynolds number[10]. Thompson et al.[11] carried out experiments to investigate the drag force produced by isolated stems in a laboratory channel. It was considered that the flow resistance is dominated by the vegetation resistance.

The presence of vegetation would lead to the appearance of secondary currents. Starr[12] studied the origin of secondary flows around a circular cylinder (in place of vegetation) spanned across a constant shear flow. Woo et al.[13] found that the horizontal vorticity pressure gradients is generated by the interaction between the shear flow and the cylinder, which would cause a downward span-wise velocity along the leading edge of the cylinder and an upward span-wise velocity on the lee side of the cylinder.

This article uses Large Eddy Simulation (LES) to simulate open channel flows with non-submerged

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