NEW METHOD FOR VISUALIZING LARGE SCALE TURBULENCE STRUCTURE BY TRACING SHEET OF PSEUDO-TRACER CLOUD

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Fluid: open-channel flow, flow with gravel bed
Visualization method(s): particle tracing
Other keywords: LES, rough wall turbulence

ABSTRACT: A new idea of visualizing turbulence structure by tracing cloud of pseudo-particles repeatedly placed in a horizontal sheet is proposed in this research. The target flow is a rough wall open-channel flow simulated by a large eddy simulation (LES). The rough wall boundary was reproduced by an immersed boundary method (IBM) which utilizes a digital elevation data (DED) of a rough bed measured by a stereoscopic method. The rough bed was composed of natural gravel particles with a mean diameter of 1.5cm placed on a flat plate. The DED is shown schematically in Fig.1. The LES was conducted for the Froude numbers of 0.3, 0.4 and 0.6 with a depth of five centimeters. The range of the Reynolds number was between 10,500 and 21,000. The calculation was executed using 85 by 100 by 100 grids under periodic boundary conditions in streamwise and lateral directions. The water surface was expressed by a density function method, therefore air flow phase as well as water flow phase was calculated in the simulation. One of the main interests in this research is to investigate the source of water surface fluctuations by turbulence with increasing the flow speed or the Froude number. In order to observe the flow structure near the water surface, a large number of pseudo-tracers, 200 by 200 in the present case, were firstly placed in a horizontal sheet at one instant and shift them according to their local flow directions. Secondly, after a short period new pseudo-tracers were installed in the same plane and shift them again. Finally, every time this procedure was executed the maximum height of the cloud of tracers was calculated at every mesh to construct a topographical image of tracers that reached the maximum elevation. The resultant figure displays a flow structure generated by a number of small fluid volumes passing upward through the horizontal plane. Fig.2 shows the results obtained for a horizontal plane placed at z=0.8H for the cases of the Froude number of 0.3 and 0.6. Here H stands for the water depth. The results are expressed as birds-eye-view to enhance the topographic feature of the structure. The flow direction is from bottom to upward. It is interesting to note that the scale of each lump of fluid is comparable to the size of the bottom roughness, which suggests that a lump of fluid separated at each roughness element has reached near the water surface by preserving its relative scale because the water depth is relatively shallow in the present simulation. The water surface fluctuation can be affected by such a motion of fluid. Further investigation with respect to the generation of large scale structure on gravel bed flow is required to understand the water surface phenomena in river mechanics.

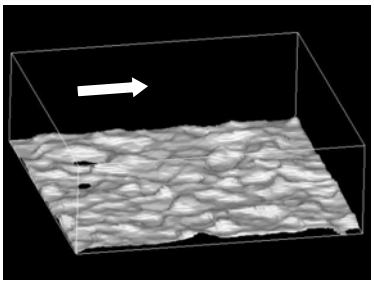

Fig.1 DED for rough bed; 27.1cm in flow direction and 26.5cm in lateral direction

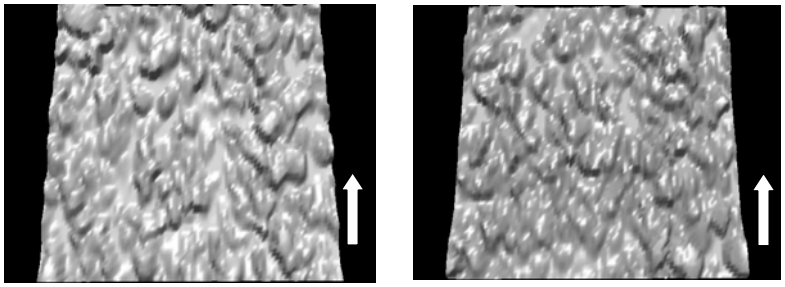

Fig.2 Large-scale structure by sheet of tracer cloud exression; Fr=0.3(left) and Fr =0.6(right)