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Vortex Formation in Shallow Flows[1]

DONALD ROCKWELL, Mechanical Engineering, Lehigh University

Vortical structures having a scale much larger than the depth of the flow, which arise in bluff body wakes, jets, and mixing layers generated in shallow layers, show distinctive features due to the influence of bed friction. Cinema techniques of high-image-density particle image velocimetry are employed to characterize quasi-two-dimensional and three-dimensional aspects of the vortex development in terms of: patterns of vorticity; flow topology involving definition of critical points; and global spectral and cross-spectral analyses, based on simultaneous time records at thousands of grid points of the cinema imaging. Taken together, these representations lead to an understanding of the relationship between coherent vortex development and unsteadiness along the bed and, furthermore, provide a basis for exploration of concepts generic to separated shear layers in shallow flows. These concepts include: suppression of a primary mode of vortex formation due to bed friction and emergence of another mode; resonant coupling between a gravity wave of the shallow layer and vortex formation, leading to large-scale vortices; and passive and active (open loop) control, which can either retard or enhance the onset of vortex formation. These studies suggest opportunities for further investigation on both experimental and numerical fronts. Collaboration with Haojun Fu, Alis Ekmekci, Jung-Chang Lin, and Muammer Ozgoren is gratefully acknowledged.

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