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Vortex dynamics around an immersed structure

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Abstract:

The interaction of waves and current with submerged structures in coastal zones generates some complex hydrodynamics features which may considerably impact the local environment. The geometrical singularities of the structures produce concentrated vortex filaments which may impact the sea bed and/or the free surface.

The objective of the present study is to characterize the vortex dynamics generated by a horizontal thin plate considered as a vortex generator, in a regular wave field. Vortices are generated at the edges of the plate. They are deformed and destroyed by three-dimensional instabilities. Their dynamics is investigated thanks to laboratory experiments conducted in a 10 m long wave flume.

The two-dimensional vortex dynamics is characterized using PIV measurements. For this experiment, mean velocity and vorticity fields all around the plate are determined in different instants for one wave period. Then, we observe the formation of downstream and upstream vortex pairs which are mutually advected toward the sea bed and the free surface respectively. These evolutions are characterized through mean vortex trajectories calculated thanks to the mean velocity fields. It shows the presence of a stagnation point at the downstream flume bottom due to the vortex pair advection and to the presence of an adjacent recirculation cell under the plate. This point will be a location of scouring phenomenon at the sea bed.

To test different geometries and wave conditions a lagrangian simulation (using *vortex method*) of the experiment has been developed to reproduce numerically the vortex wake in non stationary, two-dimensional flows. The numerical results agree with experiments.

The three-dimensional dynamics is studied thanks to stereo photography. The vortex cores are visualised with hydrogen micro bubbles generated at the edges of the plate by electrolysis. The evolution and the destabilization of the vortices are recorded by two CCD cameras focus in two different planes. Thanks to this technique, the vortices are reconstructed in the three dimensions of the space in different instants and for several wave periods. These three-dimensional instabilities are characterized by several deformation modes whose wavelength and growth rate are determined by signal processing and spatiotemporal vortex oscillations analyzes. By varying the geometry and the wave conditions we determine how these parameters control the observed three-dimensional vortex instabilities. A control of the vortex breakdown could be considered through modification of the edge of the plate geometry to avoid scouring phenomenon in the sea bed for example.

Key words:

Vortex dynamics – Marine structures – Wake – Environmental impacts – Vortex three-dimensional instabilities