Dynamics of an artificial aquatic blade subjected to von Karman vortices

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Aquatic canopies play a vital role on river bed stabilization, flood control, sedimentation, transport and mixing of nutrients or pollutants whereby, they influence the water quality for the river ecosystem. Often plants in aquatic canopies are long and flexible. Hence, in many cases, the mass transfer and mixing processes are strongly controlled by the fluid-structure interactions between aquatic plants and vortices in the mixing layer that arises from the slow moving flow through the canopy and the fast moving river flow on the canopy top [1] [2]. In this context, it is important to better understand dynamics of individual plants in the presence of vortical structures. And so, we propose a model experiment to investigate the motion of a single quasi-2D artificial blade exposed to a transverse water flow and a regular array of transverse vortices. Our experiment consists of a thin flexible polyethylene sheet of length, ($l_b = 5 - 20$ cm) that is fixed rigidly to the bottom of a 2 meter long narrow water channel. The blade free-end is then systematically excited by a von Karman vortex street. We control the frequency (f_b) and vortex size via the mean water speed (U) and the diameter of the cylindrical obstacle (d = 1 − 4 cm). Thereby, we observe two distinct dynamical regimes. (1) Rigid-body oscillations : the blade moves forth and back about a mean deflection and (2) Traveling wave regime : transverse waves originate at the blade anchorage near the channel bottom and move along the blade length towards its free-end. When the blade thickness (e_b) and length (l_b) are kept constant, the measured oscillation amplitude increases linearly with the obstacle-size based Reynolds number ($Re_d = \rho U d/\mu$) over a relatively wide range (Re_d = 200–3500). The slope of this linear Reynolds number dependence is seen to vary only with the blade rigidity, such as the thickness ratio (l_b/e_b) and the Young's modulus (E). We explain these observations via a scaling law that exploits the necessary balance between the work done by the restoring bending forces and the kinetic energy imparted by the incoming vortices on a blade. When the mean blade deformation is sufficiently large, our measurements show that traveling waves appear on the blades. The celerity of the observed traveling waves seems to be independent of the water velocity (U). In particular, we demonstrate that the transition to traveling wave regime is independent of the obstacle diameter (d) but it depends strongly on a critical Cauchy number ($Ca = 12\rho U^2 l_b^3/E e_b^3$) which relates the form drag experienced by the blade and the blade rigidity.

Références

1. M.Ghisalberti & H.Nepf, Mixing layers and coherent structures in vegetated aquatic flows, *Journal of Geophysical Research*, VOL. 107, NO. C2, 3011, (2002).
2. H.Nepf, Flow and transport in regions with aquatic vegetation, *Annu. Rev. Fluid Mech.*, **44**, 123–42,(2012).