Numerical investigation on Honji instability for oscillatory flow past a step cylinder

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The step cylinder, consisting of a small-diameter cylinder and a coaxial large-diameter cylinder, is widely used in marine engineering applications. The abrupt change in the diameter at the step causes a complicated flow pattern around the step cylinder.[1] In the present work, we investigate the step effect on the Honji instability by conducting direct numerical simulations (DNS) of oscillatory flow around an isolated step cylinder. The diameter ratio of the cylinder is $D/d = 1.8$, where D and d are the diameters of the large and small cylinders, respectively. The Keulegan-Carpenter number KC is 2.8 and the Stokes number β is 80. With this setting, the flow pattern around the small cylinder is in regime A, while the flow pattern around the large cylinder is in regime B, where the flow becomes three-dimensional due to the Honji instability.[2]

It is found that the step strongly affects the Honji instability around the large cylinder. Compared to a uniform cylinder (i.e., in the absence of a step), two new slower phenomena occur: (1) A slower generation process of Honji vortex pair, as shown in figure 1 (a); (2) a slower merging process of Honji vortices, as shown in figure 1 (b). By investigating the evolution of the spanwise flow velocity and the vortex dynamics around the step cylinder, the physical mechanisms underpinning these phenomena will be explained.

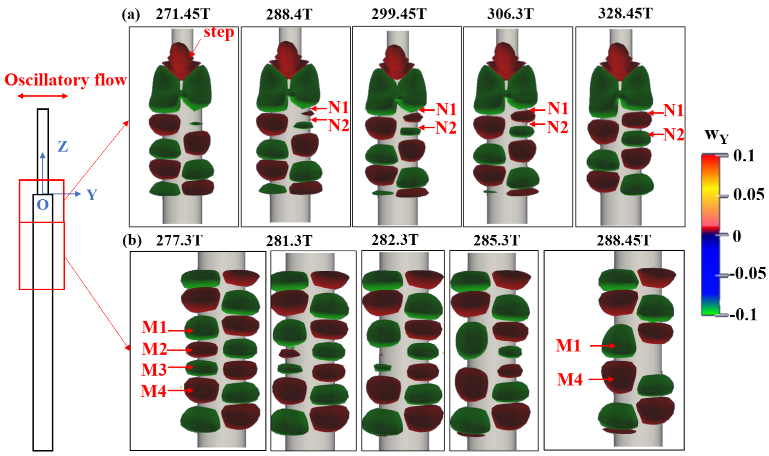

Figure 1: Vorticity isosurfaces $\omega_Y = \pm 0.1$ around the cylinder, T is the period of the free-stream velocity oscillation. (a) The generation process of a new pair of Honji vortices (i.e. vortices N1 and N2) in the region close to the step. (b) The merging process of a pair of Honji vortices (i.e. vortices M2 and M3) in the region relatively far from the step.

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[1] Tian, Cai. et al, *J. Fluid Mech.* **891**, A24 (2020).

[2] Hongji, H, *J. Fluid Mech.* **107**, 509–520 (1981).