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Linear and nonlinear dynamics of axisymmetric waves in the hollow core vortex

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The dynamics of trailing vortices are under constant investigation during last decades since it is of considerable interest to reduce aircraft wakes and associated hazards to forthcoming planes. The isolated axisymmetric vortex is the commonly used simplest elementary model when considering such issue. Although asymptotically stable, recent studies have revealed its sensitiveness to specific perturbations, leading in some cases to considerable gains of energy[1,2]. Albeit of evident interest, the underlying mechanisms of energy growth are considered in the linear regime.

The nonlinear dynamics of such vortices need also to be considered in order to complete the picture. Rather than performing direct numerical simulations[3], an interesting way to investigate it is to consider the nonlinear interactions of waves. This approach is motivated by the possible existence of resonance between wave components. For this purpose, the base flow model is simplified by considering the hollow core vortex. Arising naturally when a tank is drained (bath-tube vortex), it presents simpler dynamics than the Lamb-Oseen vortex as it only possesses two families of waves. This point is of crucial importance for the tractability of the problem.

In this work, the nonlinear temporal evolution of axisymmetric waves are investigated through numerical integration when the flow is submitted to various initial conditions (travelling or standing wave, pinching of the free surface, wave trains). We focus on wave trains as important energy exchanges between the main component and its sideband waves are observed (figure 1). This phenomenon is related to the Benjamin-Feir instability[4] (triadic resonance) occuring for wave trains on deep water.

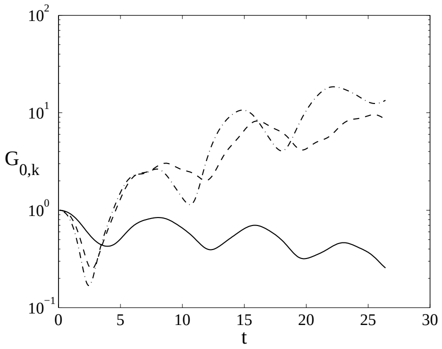

Figure 1: Energy Gain of the main component $k = 1$ (–), the upper sideband wave $k = 1.1$ (-.-) and the lower sideband wave $k = 0.9$ (- -) for $Re = 1000$ and $We = \infty$.

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