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Stratified Wake Behind an Accelerating Hydrofoil

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Abstract

Wakes of towed and self-propelled bodies moving in stably stratified flows are of relevance to environmental and ocean engineering applications. To date, the majority of studies focused on the wakes of spheres and cylinders in stratified flows. Stable stratification modulates the wake dynamics, leading to a significantly different flow compared to non-stratified wakes. The wakes of spheres and cylinders experiencing stratified conditions exhibit a life cycle composed of three regimes: a three-dimensional initial wake; a transitional, non-equilibrium regime; and finally, a quasi-two-dimensional regime. Stratified wake studies have focused mainly on late time effects of stratification where the bluff body moves with constant velocity. Yet, the case of stratified wakes behind accelerating bluff bodies from rest is not well understood. Understanding how buoyancy forces affect the initial growth of vortices during the inertial phase of a wing accelerated from rest at a constant rate may play a role, for instance, on the efficiency of the propelling underwater vehicles that accelerate or decelerate in the stratified pycnocline layer in the ocean.

In this study we present PIV measurements characterizing the wake evolution behind an accelerating hydrofoil (NACA 0015) from rest at constant rate, which is subjected to strong stratification (Fr=$O(1)$) and low Reynolds number (Re=10^3-10^4). A comparison is made between flow in the presence of stratification and without, in terms of the vorticity fields, streamwise and vertical velocity profiles, momentum thickness and vortex identification. The findings provide insight into the impact of stratification on a free shear flow, showed by smoothing and stretching of the vortices in the streamwise direction. A more rapid and different life cycle of the hydrofoil stratified wake was found compared to studies on spheres and cylinders. Hence, the findings may have long reaching consequences on the designing of future micro-air/water-vehicles, in terms of surveillance and minimum 'finger tips' traces.