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Far turbulent wake after a towed body in stratified fluid

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Evolution of a far turbulent wake after a towed body in fluid with stable density stratification is studied for the large Froude and Reynolds numbers. A simplified theoretical model to describe the far wake evolution is proposed and verified by direct numerical simulation and laboratory investigation.

Within the model, the wake is considered as a quasi-two dimensional turbulent jet flow, for which the main mechanism of spreading and decay is associated with transfer of momentum from the mean flow to quasi-two dimensional disturbances growing due to hydrodynamic instability. The calculation of the wake evolution is performed in quasi–linear approximation taking into account only development of the most unstable bending mode is considered. The diffusion equation for the mean wake flow velocity is obtained having the characteristic time scale determined by the reciprocal growth rate of the most unstable disturbance of the two-dimensional jet flow (δ_0/U_{00},whereU_{00}, δ_0 are the initial wake axis velocity and its width).

Direct numerical simulation (DNS) of evolution of a two-dimensional wake was fulfilled and compared with the theoretical model. Time dependencies of the wake integral parameters (axis velocity and transversal scale) are in good agreement with the results of the DNS (with the accuracy up to 5%). The spectra of disturbances are represented by the model with the accuracy up to 30%.

Experimental investigation of the wake after a towed body in the thermocline-type stratified fluid was performed in a laboratory tank. Instantaneous horizontal velocity field was measured by particle image velocimetry (PIV). Time dependencies of the wake axis velocity and width are in good agreement with the thetheoretical prediction.

The calculations within the model were compared with the available experimental data [1] presented versus time normalized by buoyancy frequency *Nt* alternatively to the present theoretical model, where time is normalized by δ_0/U_{00} , so nondimensional time is $T= tU_{00}/\delta_0$. It was supposed, that the universal quasi-two-dimensional regime of the wake evolution takes place when the Richardson number of the wake flow exceeds a definite threshold value $Ri_{cr}=(N\delta_0/U_{00})^2$, for which our experiments give $Ri_{cr}^{1/2} \approx 8$. Comparison revealed good agreement of the experimental data [1] and the theoretical dependencies presented versus $TRi_{cr}^{1/2}$.

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References

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