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Local gas transfer rate through the free surface in spatially accelerated open-channel turbulence

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Abstract:

It is important to determine the transport mechanisms of dissolved gases through free surfaces in open channels. Even though many physical and phenomenological models have been proposed, not much is known about the local distribution of the gas transfer velocity. Thus, this study formulated a theoretical equation for developing a concentration boundary layer in an open-channel flow. Additionally, the free-surface velocity component and the concentration of dissolved oxygen were measured in a spatially accelerated open-channel flow. In particular, the streamwise profile of concentration boundary layer thickness was measured using an extra-fine needle-type dissolved oxygen probe, and the local gas transfer rate was experimentally obtained. The present theory suggests that the local gas transfer is controlled by two significant terms: the streamwise gradient of the mean velocity and the relative intensity of turbulent diffusion. By focusing on accelerated open-channel flows with bottom-situated wedges, the formation mechanism of the concentration boundary layer was explained by a comparison with the presented theory. The comparison of the theoretical model and measurement data indicated that the contributions of both the mean velocity and turbulence diffusion are comparable and significant in the acceleration zone. The thickness of the oxygen concentration boundary layer began to decrease a bit downstream of the entrance, corresponding to the variation in the free-surface turbulence factors. The inflectional point of the concentration thickness appeared downstream of the acceleration zone and continued to decrease at the exit related to relaminarization. These interesting features are explained by the streamwise profiles of the terms in the presented theory.

Keywords: gas transfer velocity, concentration boundary layer, open-channel flow, dissolved oxygen measurement, local gas transfer, turbulence diffusion