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Spatially-averaged oscillatory flow over a rough bed

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Abstract

A rigorous framework involving flow decomposition and averaging is presented, within which the mechanics of rough- (e.g., rippled-) bed oscillatory flows can be better interpreted and understood. Spatially-averaged equations for conservation of fluid mass and momentum are developed for analyses of rapidly-changing bed conditions, e.g., for growing ripples. Where repeated observations of the changing bed conditions are available, the ensemble and spatially-averaged versions of these equations can be used for more detailed analyses of the flow dynamics.

The double-averaged (in space and phase or time) equations of mass and momentum conservation are shown to be appropriate for analyses of flows over fixed rough beds and equilibrium ripples. The value of the present framework is highlighted herein by its application to PIV-measured oscillatory-flow velocities, stresses and vorticities over growing and equilibrium wave-induced intermediate-depth orbital-vortex ripples. In particular, discussions are provided regarding the mechanisms by which gravity-induced and pressure-gradient-induced momentum is transferred to the bed, with the analysis framework naturally and explicitly including the combination of the full range of fluid stresses and boundary form and skin friction drag that is important in defining the flow mechanics.

Key words: ripple initiation, ripple growth, equilibrium ripple, double averaging, spatial averaging, PIV, vortex ripple.