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Bottom shear stress measurement technique based on ferrofluids over uniform and mixed sandy bottoms

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Ferrofluids are stable colloidal suspensions of magnetic particles in a liquid carrier. In the presence of an external magnetic field, ferrofluids become magnetized as the magnetic moments of the particles orient along the field lines almost instaneously. An innovative measurement technique of bottom shear stresses based on the use of magnetized ferrofluids is proposed.

The aim is to overcome some of the limits of state-of-the-art instruments. For example widely adopted velocity and shear stress measurement techniques based on acoustic and optical approaches cannot measure very close to the bottom, mainly due to the following constrains: i) size of the sampling volume and ii) undesired reflection and disturbances induced by the bottom itself. Constant Temperature Anemometry (CTA) is also used, but probes are damaged by the sediment particles.

During the experimental campaign, a small quantity of ferrofluid O(0.01ml) is located at the bottom of the hydraulic channel. An external permanent magnetic field generates a conical ferrofluid drop (height about 1 mm). In the absence of flow, the drop is symmetrical, whereas in the presence of flow the shear stresses at the bottom cause a deformation of the drop in the flow direction. An optical readout strategy allows to measure the horizontal displacement Δ_x of the apex of the ferrofluid sensor. Such a displacement is then related to bottom shear stresses.

Optical measurements are acquired adopting a Nikon D7200 reflex camera mounting Tamron fixed focus lens having a 90 mm focal length. Experiments are carried out with constant magnetic field and varying the flow conditions (18 hydraulic configurations). Calibration of the technique is carried out with shear stress measurements indirectly estimated using a Vectrino profiler. The calibration curves show the bottom shear stresses as function of the ferrofluid apex displacements. Calibrations are performed both in the presence of a rigid bottom and in the presence of a sandy bottom.

In the presence of mobile bed, the tests are carried out both with uniform sediments and mixed sediments. Shear stress measurements acquired with the proposed innovative technique in the presence of sediments are useful for the identification of the incipient motion of sediment transport ($\tau > \tau_c$). In case of uniform sediments results agree fairly well with the classical literature results (Shields diagram's prediction), indicating the applicability of the proposed measurement technique also in the presence of moderate bed load transport.