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Ferrofluidic sensor for the experimental estimate of wall shear stresses

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The incipient motion of bimodal mixture is investigated through physical modelling using an innovative measure technique of bed shear stresses. The research is mainly devoted to the development of this novel approach wishing to overcome the different disadvantages of established instruments. Among the disadvantages, the two more restrictive ones are the poor capability to provide point-measure of wall shear stress and the difficulty to apply them for morphological studies.

In order to provide an alternative laboratory measurement technique, first Andò et al. (2009) have proposed the possibility to develop technologies based on the use of ferrofluids. The principle of operation of this technique is based on the peculiar characteristics of ferrofluids namely their capability to interact and react to external magnetic field changing their shape and their viscosity (Rosensweig effect and magneto-viscous effect). Later, Musumeci et al. (2018) have used ferrofluids, creating a single conical drop of magnetized ferrofluids located at wall to obtain the wall shear stress estimates through an inductive readout strategy. For low shear stresses, inductive system seemed to be not able to sense the deformation of the ferrrofluid.

Building on the work of Musumeci et al. (2018), the present research aims to exploit ferrofluidi sensor for shear stress measurements over bottoms by adopting an optical readout strategy. Here, the ferrofluidic sensor consists in a magnetized drop of ferrofluid located at the channel bottom, that it is exposed to different flow conditions and its deformation is video-recorded. Thanks to the application of image analysis processes is possible to investigate the relation between shear stresses and sensor deformation. Experimental activities are carried out in the presence of different sandy bottoms (10 configurations, including uniform fine and coarse sand, bimodal sand mixtures and mixtures of sand and gravels), investigating a wide hydrodynamic range of steady flows conditions (14 configurations, above and below critical bed shear stresses).

Results show that the best parameter for describing the ferrofluid drop deformation is the apex displacement. The ferrofluid sensor is sensitive to changes of bottom roughness and it is able to automatically detect the threshold of motion of different type of sediments and mixtures. Moreover, tests carried out with different sandy bottoms characterized by different roughness provides insights about the sensitivity of the proposed technique event to low shear stresses. Finally, the repeatability tests confirm the higher accuracy of the proposed measurement technique in the presence of lower shear stress regimes.