Development, calibration and testing of a miniaturized instrumented particle for the study of entrainment of solids in turbulent flows

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Infrastructure damage due to riverbed and bank destabilisation or localised scour may result in considerable financial costs and even loss of life. As the risk to infrastructure keeps increasing due to climate change, the need to directly monitor it becomes crucial. Typically, hazards assessments for infrastructure near water are performed using relatively expensive and indirect methods that require field visits to remote and harsh environments to obtain mean flow measurements, using acoustic Doppler velocimetry [1], laser Doppler velocimetry [2] or water level stations along with discharge hydrographs [3]. In this work, a miniaturized instrumented particle that can provide a direct, non-intrusive and accessible method for the assessment of coarse sediment particles entrainment is developed, calibrated and tested. The particle has a diameter of only 3cm and is fitted with inertial microelectromechanical sensors (MEMS) that enable recording its three-dimensional displacement [4, 5]. The sensor is capable of recording acceleration, angular velocity and orientation at a rate of up to 1000Hz and has deployment time of at least one hour. The data can be transferred and downloaded to a PC or an SD card at a fast transfer rate and in easy format for further analysis. The calibration process of the sensor consisted of simple physical motions and the results of the calibration show that the uncertainties in the calibration experiments and in the accelerometer's and gyroscope's readings are deemed acceptable. The uncertainty quantification and noise estimation for the sensors, provide the input of the appropriate fusion filter that is applied to the raw data to achieve uncertainty reduction. The testing process consisted of moving the particle on a micro-bed topography and using a camera to record the distance it moved. The orientation of the instrumented particle during testing is determined by inertial sensor fusion of the raw readings of the 3 sensors. The results show that the instrumented particle's motion could be detected accurately and therefore it could provide a method for direct assessment of the sediment entrainment due to hydrodynamic forces at low cost and in a non-intrusive and direct manner. The instrumented particle presented has a potential of use in a wide range of future applications around the fields of geosciences and environmental and infrastructures monitoring where sediment entrainment [5] and transport [6] is considered to be the governing process.

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