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Pressure-based impact method to count bedload particles

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Bedload transport processes determine morphological changes in fluvial, estuarine and coastal domains, thus impacting the diversity and quality of ecosystems and human activities such as river management, coastal protection or dam operation. In spite of the advancements made in the last 60 years, driven by the improvements in measurement techniques, research efforts on grain-scale mechanics of bedload are still required, especially to clarify the intermittent nature of bedload, its stochastic structure and its scale dependence.

A new impact-based device to measure bedload transport – MiCas system – is presented in this work. It was designed to meet the following key requirements: simple data output composed of time instant and location of impacts; no need for post-processing – impacts determined through hardware and firmware; capable of computing simple statistics in real time such as cumulative particle counting and discrete lateral distribution of cumulative particle counts; able to run for very large time periods (days, weeks); ability to detect particle impacts of large size fractions that are separated by a few milliseconds; composed of robust and relatively cheap components.

The system's firmware analyses pressure time series, namely recognizing the imprints of impacts of individual particles as they hit pressurized membranes. A pattern analysis algorithm is used to identify the impact events. The implementation of this principle in a dedicated microprocessor allows for the real-time measurements of particle hits and cumulative particle count.

To validate the results obtained by the MiCas system, Experiments were carried out in the 12.5m long and 40.5cm wide glass-sided flume of the Laboratory of Hydraulics and Environment of Instituto Superior Técnico, Lisbon. This flume has two independent circuits for water and sediment recirculation. A cohesionless granular bed, composed of 4 layers of 5 mm glass beads, subjected to a steady-uniform turbulent open-channel flow, was analysed. All tests featured a period of 90 s data collection. For a detailed description of the laboratory facilities and test conditions see Mendes et al. (2016). Results from MiCas system were compared with those of obtained from the analysis of a high-speed video footage.

The obtained results shown a good agreement between both techniques. The measurements carried out allowed to determine that MiCas system is able to track particle impact in real-time within an error margin of 2.0%. From different tests with the same conditions it was possible to determine the repeatability of MiCas system. Derived quantities such as bedload transport rates, eulerian auto-correlation functions and structure functions are also in close agreement with measurements based on optical methods.

The main advantages of MiCas system relatively to digital image processing methods are:

a) independence from optical access, thus avoiding problems with light intensity variations and oscillating free surfaces;

b) small volume of data associated to particle counting, which allows for the possibility of acquiring very long data series (hours, days) of particle impacts. In the considered cases, it would take more than two hours to generate 1 MB of data. For the current validation tests, 90 s acquisition time generated 25 Gb of images but 11 kB of MiCas data. On the other hand the time necessary to process the digital images may correspond to days, effectively limiting its usage to small time series.

c) the possibility of real-time measurements, allowing for detection of problems during the experiments and minimizing some post-processing steps.

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References

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