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PREFACE - SPECIAL ISSUE

Experimental methods and instrumentation in hydraulics

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Further development of instrumentation and software for hydraulic measurements, data analysis and visualization allows for a more comprehensive understanding of hydraulic phenomena. Although numerous new opportunities are arising, new challenges are also coming up, both in the application of the methodology and instrumentation itself.

On the one part, the advanced methods and techniques are significantly contributing to a more comprehensive approach to analyzing research problems, enabling the testing of new theories and adding new study possibilities. Such advancements are particularly important for experimental studies, which rely on good data and up-to-date methodology. On the other side, the setup of new equipment often requires the development of custom solutions, as well as new skills and experience to interpret the data.

In-line with the available equipment, laboratory setups, and techniques, it is necessary to exchange knowledge and experience to identify the best solutions for solving challenging research problems. However, this information is rarely covered in scientific communication, and a major effort is needed to streamline the use of experimental methods and laboratory instrumentation in hydraulics.

This Special Issue is providing an overview of methods and instrumentation commonly used in studies at a laboratory scale. It also demonstrates common problems and solutions that could be replicated and eventually contribute to new findings that would fill the gap in understanding fluid dynamics.

Experimental measurement techniques and hydraulics are strictly connected. Observation and theoretical framework in science advanced closely with reciprocal feedback: instruments design reflects the expected process to be investigated meanwhile new observations are enabled by measurement technologies advancement. This poses a semantic issue about science and observation and the practical need of choosing the measurement technique suited to the expected process magnitude and variability.

Advanced methods extend measurement capabilities which depend on instrumental parameters setting, further broadening the required knowledge for researchers and practitioners. This is particularly relevant while investigating fluid turbulent motion and transient phenomena which challenge instrument capabilities: indeed, the applied measurement technique must cope with the expected time and spatial variability. For example, the Acoustic Doppler Velocimeter proved to be a suitable instrument providing high enough sampling frequency and detailed measurement volume for turbulence characterization around boulders and or fixed structures (Aamir and Ahmad 2021; Bauri 2022; Golpira et al. 2022). The accuracy of such devices enables the investigation of turbulent kinetic energy, shear stresses and turbulence anisotropy, which was shown by Taye and Kumar (2022) in laboratory experiments in a sinuous channel. Similarly, Balouchi et al. (2022) has investigated the flow pattern over a fully developed bed at a 60º river confluence, including a constant supply of sediments. The results showed that the flow pattern differs in different sediment transport conditions, and that by increasing the bedload ratio the flow deflection of the outer bank and the shear stress decreased

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around 50%. Furthermore, the bistatic configuration of the Acoustic Doppler Velocity Profiler enabled detailed velocity profiling close to the boundary that was relevant to assessing the shear stress at bounded flow. This required fixing the instrumental parameters to the expected velocity magnitude along the entire profile from almost zero very close to the wall to flow core velocity outside the boundary layer (Liu et al. 2022). The transient flow effect on bedload transport was successfully investigated by image and ultrasound-based techniques (Przyborowski et al. 2022) that again bore out the capability of advanced techniques in observing challenging processes in terms of spatial and time resolution required.

The river's hydro-morphology is driven by both bedload and suspended load, which is especially impactful for engineers. For example, Hamidifar et al. (2022) investigated scour countermeasures around piers by using different shapes of slots. Another engineering problem with sediments is how to sample them, particularly in the case of the material moving close to the bed. Conventional bedload sampling methods have large uncertainty, especially in terms of bedload monitoring, making it harder to understand this complex phenomenon. In their study, Ermilov et al. (2022) proposed a novel, image-based approach to quantify gravel bedload transport by combining two different techniques: Statistical Background Model and Large-Scale Particle Image Velocimetry.

Another solution to monitor the suspended sediment load is to use Acoustic Doppler Current Profilers merged with optical backscatter sensors. However, such a method needs to be calibrated to the specific river cross section. A recent study on the Danube River (Pomázi and Baranya 2022) showed a case where the tributary inflow upstream disturbed the sediment load distribution. The researchers showed the main factors influencing the suspended sediment concentration patterns measured by the near-bank sensors and proposed a correction method to reliably recalculate those into the suspended sediment load.

The PIV error estimation is an ongoing challenge and its analytical description varies from one to another approach. Cameron (2022) proposed a new expression for analytically estimating the mean error and error variance, derived from iterative deformation method algorithms. A theoretical approach that was verified with synthetic image testing several known sources of error. The sedimentation in reservoirs is a serious problem usually followed by a number of operational, ecological, social, and economic issues. Pishgar et al. (2022) proposed a new type of silting basin, denoted a Dam-Type Sediment Excluder (DTSE). The DTSE was tested in laboratory conditions resulting in 25–40% efficiency in different conditions.

Apart from sediment transport, also the presence of in-channel and riparian vegetation plays a major role in driving fluvial dynamics, changing the flow structure and creating turbulence patterns. In their experimental study, Rahim et al. (2022) investigated the flow structures and turbulence parameters in an asymmetric non-prismatic compound channel with different vegetation densities placed in a divergent floodplain.

Pecly and Paiva (2022), Molteni Perez et al. (2022), and Wu et al. (2022) discussed the use of natural and artificial tracers to investigate the complex dynamics of water flow not only at the laboratory scale but also in the field. All these works pointed out the need of performing additional studies to adequately calibrate the methods used to investigate the mixing phenomena. Although each work proposed a different workflow and new algorithms, they agree on the opportunity to move from a user-based, subjective approach toward a more objective machine-based approach, integrating software routines or even machine learning to obtain more robust and less-user-dependent methods in the future.

Extensive data sets and numerical models can enable the characterization of complex flows with high value for the applications, as highlighted by Tripathi and Pandey (2022) in their review of past research on flow patterns and scour around spur dikes. However, data sets need to be large, homogeneous to allow intercomparison, and of good quality to enable the validation of numerical models. Data-driven models and machine learning could help overcome some of these challenges in the future. The combination of extensive datasets and up-to-date data analysis tools is also very important in investigating phenomena like particle settling, as demonstrated by Shivashankar et al. (2022), or gravity currents, as shown in the work of Adduce et al. (2022).

The study presented by Eslami et al. (2022) applied flume experiments to test definitions of bed elevation, a critical parameter in solving hydraulic problems. Two contrasting definitions of bed elevation were tested numerically, pointing out the opportunity to locate the bed below the bedload layer.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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