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Hydro-acoustic Techniques in Hydraulics Engineering

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Abstract

Underwater sound techniques began since Leonardo Da Vinci which listened to approaching ships by using a tube in water and placing its outer extremity to hear. The sound speed into water was firstly measured on Lake Geneva in 1826 whereas the modern acoustics is due to Lord Rayleigh which lived in the late 19th and early 20th century. In spite of these well consolidated bases, the using of acoustic techniques in hydraulics is pretty recent and developed in parallel for laboratory and field applications. Ultrasound techniques are particularly relevant in case of opaque fluids and for no optical access through boundaries. This talk delineates important features of hydro-acoustics and the instruments used. Some experiences show the acoustic investigation of sediment transport, which has always been a challenging task in riverine environment, and sea waves tests carried out at the hydraulic laboratory of the University of Bologna.

Keywords: hydro-acoustics, Doppler effect, backscatter, sediment transport, waves impact.

1. INTRODUCTION

Hydro-acoustics is a quite novel discipline which is the application of underwater sound to investigate a variety of parameters in hydraulics (e.g., water depth, flow discharge, suspended sediment concentration, bedforms). The using of underwater sound began since centuries but technical advancement were mainly produced while aiming at locating submarine targets during the world wars which gave rise to SOund Navigation And Ranging technology (i.e., SONAR) and has laid the foundation for following environmental, engineering and medical applications. Particularly relevant for the hydraulic engineers, the development of the Acoustic Doppler Current Profiler – ADCP (Gordon 1996) and the Ultrasound Velocity Profiler – UVP (Takeda 1986) enabled the velocity profiling of a water column in the field and in laboratory, respectively. Both these technologies relies on the scattering back of sound from particles transported by the fluid flow. The projected sound by active transducers is then received at the same transducers that is typical for mono-static configuration. The receivers and the projector are different transducers in the bistatic configuration which was evenly implemented for punctual measurement, the Acoustic Doppler Velocimeter – ADV, and more recently for velocity profiling: the Acoustic Doppler Velocity Profiler – ADVP (UBERTONE 2019). Emitted and received signals differs of the Doppler shift that is linearly correlated with the particles velocity by means of speed of sound into the fluid. While this represents a direct velocity measurement (i.e., with no need for calibration) a number of physical limitations must be carefully considered when designing an experimental campaign. These affect the measurable range, the resolution and accuracy and undermine the reliability of measured velocity profiles. This combines with the signal modulation and following processing adopted by instrumental developers. As a matter of fact different technologies developed depending on the targeted application. For example the ADCP uses the broadband technology which enables accurate and detailed profiling in a variety of field conditions but makes the returning signal uncorrelated in case of extreme conditions. Differently, the UVP typically applies two pulse coherent technique which is subjected to Aliasing but allows a larger control to end users.

2. EXPERIENCES IN USING HYDROACOUSTC TECHNIQUES

Laboratory and field applications parallelly developed and a number of acoustically based methodologies thrived aiming at measuring specific parameters and for well-defined ranges. In any case, hydro-acoustics is particularly relevant in case of opaque fluids that is exactly the case of sediment transport measurement in the turbid river flow, and for no optical access through boundaries that may be the case of many experimental set-ups in the hydraulic laboratory (e.g., wavy water surface). Therefore, we aimed at characterizing the suspended sediment transport and bedload in rivers by using the ADCP that is usually available in the field for river flow discharge measurement. This research effort entailed the testing of backscattering, mono-static and bi-static technologies (i.e., UVP and ADVP) under controlled condition in different laboratories which produced some methodologies for the profiling of suspended sand from river bed in large rivers (Guerrero and Lamberti 2011; Guerrero et al. 2013; Szupiany et al. 2019), the continuous monitoring of suspended sediment transport at river channel stream (Guerrero and Di Federico 2018; Aleixo et al. 2020) and the estimation of bedload rate at riverbed (Conevski et al. 2019, 2020). Furthermore, we applied the UVP in experimental set-ups characterized with wavy surface and transient conditions partially disabling optical methods deploying from water surface. These were the cases of reconstructing the hydraulic conditions which mobilized coastal mega boulders (Bressan et al. 2018) and the testing of overtopping processes at scaled dikes (Gaeta et al. 2020).

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