DEXMES: A novel cylindrical device for SPM experiments

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1. Introduction

A novel laboratory device was developed to generate homogeneous suspended sediment concentration and to provide sufficient volume, ≈ 1 m^3, for several sensors functioning simultaneously. The hydrodynamic characteristics and the functionalities of the new device were evaluated. Experiments using four types of sediments were also conducted to investigate the capability of the device in maintaining a homogeneous suspension under different flow conditions.

2. The DEXMES device

The DEXMES device (dispositif expérimental de quantification des matières en suspension) consists of two main components. The upper part is a cylindrical tank with an inner diameter of 0.96 *m* and 1.4 *m* high. In order to break up the large vortexes and mitigate the vortex-induced bubbles, e.g., generated by the impeller, four evenly-spaced baffles with dimensions of 0.09 x 1.31 *m* are attached to the inner side of the tank (Figure 1). The bottom part of the DEXMES device is a convex, elliptical-shape Plexiglas bed. An impeller with a diameter of 0.36 *m* placed approximately 1 *m* below the water surface generates a turbulent flow in the tank. The speed of the impeller, ranging from 0 to 235 *rpm*, is regulated by a controller box.

3. Hydrodynamics and SPM experiments

The mean velocity structure of the DEXMES was quantified based on ADV measurements of the three velocity components, i.e., U, V, W, at frequency 32 *Hz* over a 5 *min* burst for each measurement (Figure 1). Measurements were collected over a grid of 8 x 5 points within a radial plane of the tank, with 10 x 10 *cm* grid size. The velocity profiles and turbulence distributions, eg., TKE and turbulent energy dissipation, throughout the tank then were extracted accordingly.

Four different types of particles, i.e., kaolinite, polystyrene beads, natural mud and bentonite, fine (d_{50} = 100 μm) and medium (d_{50} = 200 μm) sands were tested. At impeller speed of 175 *rpm* and for 6 concentrations ranging from 15 to 200 *mg/L*, 1 *L* water samples were collected at different positions or coordinates, e.g., nozzle 2 (35,25), nozzle 4 (35,65), bucket water sample (0,25) (Figure 2).

4. Results and Conclusions

Figure 1 shows that the tank can be virtually divided into two zones, i.e., above and below row 4 (about 40 *cm* above the impeller), due to the flow structure. In the upper zone, the flow velocity was relatively low, reducing from row 4 to the water surface at the center of the tank, e.g., light blue color, w ≈ 0 cm/s (top right panel, Figure 1). Whereas the lower zone has higher velocities, by almost two orders of magnitude, e.g., dark blue color, w ≈ 73 *cm/s*. Applying energy spectrum in the inertial subrange

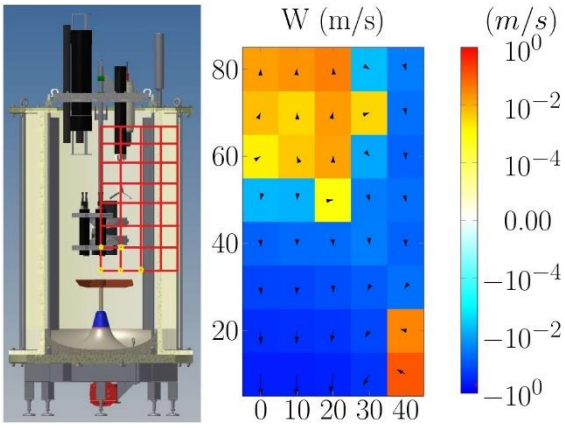

Figure 1. DEXMES device with 8 by 5 grid of ADV measurement positions and the velocity field obtained from ADV. Impeller speed is 175 *rpm*.

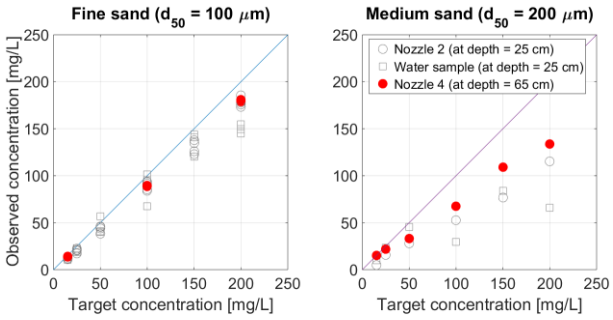

Figure 2. DEXMES provides homogeneous suspension for mud and fine sand (left). Vertical gradient in concentration and deposition occur for medium sand (right).

to calculate turbulence dissipation rate, and hence shear stress profile, G, shows that depending on the impeller speed and positions inside DEXMES, G varies from 1 to 140 s^{-1}. Visual observation during the experiments and detailed data analysis also reveal that there are strong upward current bursts raising from the bottom and along the tank wall, particularly close to the baffles.

The SPM experiments show that DEXMES efficiently maintains homogeneous conditions for bentonite, natural mud, and fine sand. There are deposition and vertical gradients in concentration for medium sand, which can be mitigated by increasing the flow turbulence i.e., increasing the impeller speed up to 235 *rpm*. However, a stronger current might introduce unwanted bubbles, influencing acoustic sensors' performance. The stratification for medium sand and the impact of bubbles are under further investigation.