TURBULENT FLOW INDUCED BY OSCILLATING CIRCULAR CYLINDER ARRAYS

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BACKGROUND AND AIM

Vegetation association plays important role in the shallower coastal zone for sediment control and the nutrient and carbon absorption. It is necessary to understand the fluid motion including turbulence in the vegetation so that we may evaluate precisely shallow water region including vegetation and wet land. As the first step of research on fluid motion in the vegetation, circular cylinders are sometimes used. Many researches on the fluid force acting on the circular cylinder and fluid motion around the cylinder have been achieved so far. However, the properties of turbulent flow induced around circular cylinders in a wave, especially turbulence transition mechanism and spatial-temporal distribution of turbulence, are not almost investigated.

The purpose of this study is to understand the fluid flow including turbulent induced by wave transmitting vegetation association. In this study fluid motion was measured by oscillating circular cylinder arrays in a tank by using the PTV technique (Figure 1).

CONTENTS

Circular cylinder arrays (the diameter d=0.049 m) were oscillated with the period T in a tank 1.6 m long, 0.54 m wide, and 0.4 m high. In the experiment, the distance DY/d between circular cylinder arrays in direction of oscillation was fixed and that in transverse direction DX/d was varied 1.24, 1.65 and 2.49. The fluid motion in the gap of cylinders was measured using PTV technique. A laser light sheet was irradiated horizontally. The images of tracers preliminarily seeded in a tank were captured by two synchronized high speed cameras equipped on the beam moving with oscillatory cylinder arrays under the tank with 300 fps. Spatial average velocity v_S at grid points was calculated from measured velocity v_m at the detection points of tracer. Further turbulent velocity was defined as $v_t = v_m - v_S$ *in this study.*

A series of the experiments were conducted under different the Reynolds number $Re = V_{f0}d/\nu$ and the KC number $KC = V_{c0}T/d$, where $V_{f0} = DX/(DX-d)V_{c0}$ is the velocity amplitude between circular cylinders, V_{c0} is the velocity amplitude of circular cylinders, and ν is kinematic coefficient of viscosity.

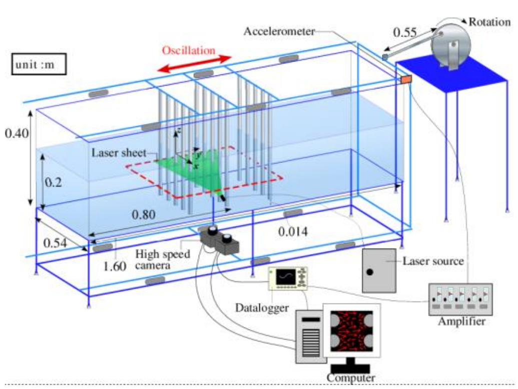

Figure 1 Experimental apparatus

MAIN RESULTS

Figure 3 shows the time variation of spatial averaged velocities at the fixed points P_A, P_B, P_C, P_D shown in Figure 2. It is clear that spatial averaged velocities vary with phase difference from the phase of cylinder oscillation velocity V_f. It is interesting that the violent fluctuation were generated when v_S exceeded some critical level.

Using turbulent velocity v_t, spatial averaged turbulent energy $\langle K_S \rangle$ was obtained. According to the measurement $\langle K_S \rangle$ in the downstream area from the gap of cylinder becomes larger and $\langle K_S \rangle$ behind cylinder becomes smaller for the case of in-line arrangement of cylinders. For the case of staggered arrangement, $\langle K_S \rangle$ behind cylinder is larger than that for in-line arrangement.

Figure 4 shows the spatial averaged turbulent energy $\langle K_S \rangle_{xy}$ in the integral domain as shown in Figure 2 for DX/d=1.24, 1.65, 2.49. It is clear that disturbance of $\langle K_S \rangle_{xy}$ becomes larger with increase of Dx/d. Further, it is found that the phase variation of $\langle K_S \rangle_{xy}$ is different from the oscillation velocity phase of cylinder V_f and that the phase lag becomes larger as Dx/d is smaller.

The knowledge of mean, maximum and minimum of turbulent energy are sometimes very useful for engineering applications. Figure 5 shows the mean, maximum and minimum of $\langle K_S \rangle_{xy}$ during a period for the case of in-line and staggered arrangement. It is found that $\langle K_S \rangle_{xy}$ in the in-line arrangement is larger than the one in the staggered arrangement. Although the maximum of $\langle K_S \rangle_{xy}$ seems to become larger, the mean and minimum of $\langle K_S \rangle_{xy}$ don't seem to vary with Re. In the presentation, the relation between $\langle K_S \rangle_{xy}$ and KC will be also presented.

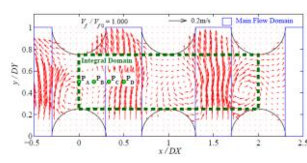

Figure 2: Distribution of spatial averaged velocity

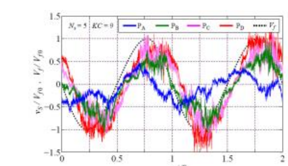

Figure 3: Time variation of spatial averaged velocity

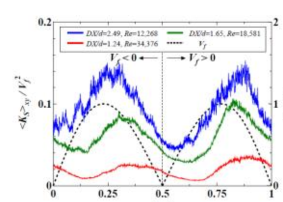

Figure 4: Phase variation of spatial averaged turbulent energy

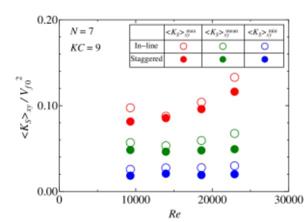

Figure 5: Relation between turbulent energy and *Re*