EXPERIMENTAL RESEARCH OF VORTEX STRUCTURE OF THE FLOW AROUND A HORIZONTAL CIRCULAR CYLINDER AT VARIOUS GAP-RATIOS IN THE CROSS-FLOW OF SHALLOW WATER

QI E-RONG[1], LI GUO-YA[2], LI WEI[1], WU JIAN[1], and ZHANG XIN[3]

[1]State Key Laboratory of Water Resources And Hydropower Engineering Science, Wuhan University, Wuhan 430072, China
(Tel: +86-27-68772206(O), Fax: +86-27-68772310 e-mail: erqi@whu.edu.cn)
[2]China Three Gorges Project Corporation, Yichan, 443002, China
[3]Central South Building Design Institute, Wuhan, 430071, China

In the gap-ratio range of $0.0 \le G \le 7.0$ (i.e. from the point when a circular cylinder touches the bottom wall to the point when the circular cylinder touches the water surface), a particle image velocimetry (PIV) is applied to conduct a systematic experimental research of the flow around a horizontal circular cylinder in the cross-flow of shallow water. The velocity distribution of transient flow field at various gap-ratios is obtained. Based on these data, the phenomena and rules of the vortex and its course of generation, development and evolvement at various gap-ratios are analyzed, and it is found that there are similar unshedding vortex structures at G=0.0 and G=7.0, and others are structures of shedding vortex. The figures of typical vortex movements are given. Based on this, the differences between the transient flow field and the time-averaged flow field and the characteristics of the vortex structures are analyzed. The findings of this paper are of guiding significance for engineering issues with similar flowing features.
Keywords: flow around a circular cylinder, vortex structure, PIV

1. INTRODUCTION

The flow around a horizontal circular cylinder near a plane boundary (fixed wall) is of great significance in Hydrodynamics. In the earlier period, there are those of Bearman and Zdravkovich(1978), who studied the flow at Reynolds numbers of 2.5×10^4 and 4.8×10^4 and at values of Gap-ratio G=0~3.5 by way of wind tunnel experiment, visualized the flow field by using smoke wire method, and measured the pressure distributions around the cylinder and along the plate, according to which they concluded that Strouhal number St=0.2 keeps a constant so long as $G\ge0.3$. Fredsφe and Hansen(1987), Lei et al. (1999), Tanida et al. (1973), Wu Jian et al. (2005) studied also the flow around a horizontal circular cylinder near a plane boundary. So far, there have not been many experimental researches into the flow around a horizontal circular cylinder in cross-flow.

2. EXPERIMENT EQUIPMENT AND METHODS

The experiment is conducted in a glass water channel of 100cm×50cm×2000cm (W×H× L). And the horizontal circular cylinder made of plexiglass for the experiment is placed in the rear-middle part of the measuring section of the channel. PIV laser velocity measurement system is used as the major measuring instrument in the experiment.

G (Gap-ratio) is defined as the ratio between e, the distance from the lower wall of a circular cylinder to the flat bottom wall and D, the cylinder diameter, i.e. $G = e/D$ (refer to

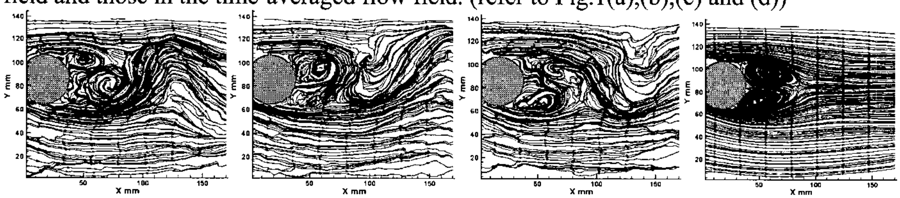
Fig. 1). A series of experiments are carried out on the flow around a horizontal circular cylinder in the cross-flow of shallow water at G = 0, 0.5, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0.

3. CONCLUSION

(1) Taking water as the object of study, this paper conducts systematic observation and measurement of the process of the steady flow around a circular cylinder in the cross-flow of shallow water via advanced PIV measuring technique, and obtains a large amount of explicit data of transient flow field. These data help to do some further research into the unsteady and time-averaged characteristics generated in the movement and development of the vortex during the process of the flow around a circular cylinder in the cross-flow of shallow water. This study indicates that the flow in the wake flow zone behind the cylinder is local unsteady flow, the main feature of which is the generation and development of vortex in shear layer.

(2) The comprehensive research and analysis indicates that the vortex structures in the wake flow zone of the flow around a horizontal circular cylinder at G=0.0 and G=7.0 are obviously different from those at $0.5 \leq G \leq 6.0$. When G=0.0 and G=7.0, i.e. the circular cylinder touches the bottom wall and the water surface, there are non-shedding vortex structures present in the wake flow zone of the flow around the circular cylinder. When $0.5 \leq G \leq 6.0$, there are shedding vortex structures present in the wake flow zone of the flow around the cylinder, which keep generally the same at different range of gap-ratios. As the change of the vortex structure in the wake flow zone affects the change of the borne force on the circular cylinder, it can be deduced that the borne force on the circular cylinder, when it enters the water and it is at the bottom, is quite different from that when it is in the middle of the flow, i.e. under the circumstances that $0.5 \leq G \leq 6.0$. (refer to Fig.1)

(3) In the transient flow when $0.5 \leq G \leq 6.0$, there are two vortices shedding alternately at the upper and lower sides of the cylinder behind the circular cylinder, developing and dispersing with the flow; whereas there regularly and steadily exist a pair of vortices--(one above the other)--in the wake flow zone behind the circular cylinder in the time-averaged flow field. And there is a great difference between the vortex structures in the transient flow field and those in the time-averaged flow field. (refer to Fig.1(a),(b),(c) and (d))



(a) T=0 (b) T=0.534 s (c) T=1.068 s (d) the time-averaged state

Fig. 1 The moving process of the vortex in the wake flow zone of a circular cylinder at G=6.0

REFERENCES

Bearman, P. W., Zdravkovich, M. M., 1978. "Flow around a circular cylinder near a plane boundary." *J. Fluid. Mech.*, vol. 89, part 1, pp. 33-47.

Adrain, R. J., 1991. "Particle-imaging Techniques for experimental fluid mechanics." *Annual Review of Fluid Mechainics*, 23, pp. 261-304

Lei, C., Cheng L., and Kavanagh K., 1999. "Re-examination of the effect of a plane boundary on force and vortex shedding of a circular cylinder." *Journal of Wind Engineering and Industrial Aerodynamics,* vol. 80, pp. 263-286