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Experimental study of subsurface vortices in pump intake with an improved diversion-cone

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Abstract. An improved diversion-cone is designed to suppress subsurface vortices in pump intake. In experiment, the influences of size and location of the improved diversion-cone on the subsurface vortices in pump intake were studied. Experiments were conducted in a rectangle intake and 12 operating points were carried out, and the vortex frequency and vortex location were also measured. The results show that the new improved diversion-cone employed in the experiments has obviously positive effect in suppressing the generation of subsurface vortices. It is also found that the lower distance between the pump bell and the improved diversion-cone, the more frequency of free surface vortices occurred.

1. Introduction

Pump sump are widely used in small and medium pumping stations. It plays an important role in providing excellent environment for pump withdrawing water. The good conditions of incoming flow in the sump play an important role in keeping good flow field for the pump inlet which directly exerts an influence on pump system performance [1]. However, pump intakes are often accompanied with a number of free surface and subsurface vortices [2]. When such vortices occur in the vicinity of the pump intake, performance of pump decrease, resulting in loss of efficiency, vibrations or uneven impeller loading [3-5]. Hence, it is necessary to study and seek some effective vortex suppression schemes.

Previous studies have revealed that one of the reasons for the generation of these vortices is the nonuniformity of the approach flow. The vortex generation mechanism and suppression in pump sump have been studied through numerical simulation [6-10]. Tang et al [8] designed the cross-baffle conical and side-wall baffle for pump intake. Through numerical simulation, they found that it could attenuate vortices strength. In experiment, Cai Kun [11] suggested that diversion-cone was one of effective way to suppress the vortices. Ahmad et al [12] also designed the conical vortex breaker and studied the influence of vortex breaker on vortex experimentally. Nevertheless, those devices have immovable location, which limits their adaptability and application.

In this paper, a new improved diversion-cone is presented, which can be fixed with pump bell. Therefore, the diversion-cone can be moved with pump. The size and location of the improved diversion-cone are especially tested to broaden its application arrangement.

2. Experiment investigation

2.1 Experimental subject

The experimental subject in the paper is the improved diversion-cone (figure. 1), which consists of two orthogonal vertical baffles and a plate. Dimensional parameters of the improved diversion-cone are presented in the table 1. It can be easily fixed under the bell-mouth through screws.

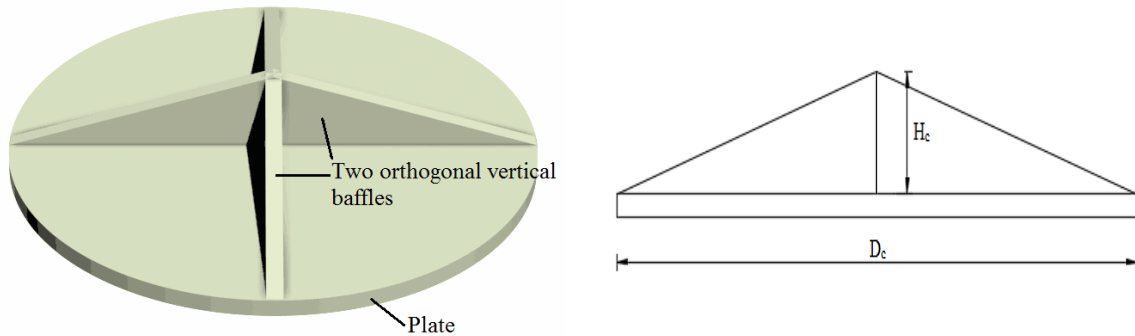


Figure 1. Geometry of the improved diversion-cone and main geometry parameters.

Table 1. Dimensional parameters.

	H_c [mm]	D_c [mm]
Type 1	40	265
Type 2	60	265
Type 3	80	265

2.2 Experimental model

Figure 2 shows the schematic diagram of the laboratory model, including the test intake, the axial pump system and pressurized pipe system. The back and side walls of the pump sump are made of Polymethyl methacrylate (PMMA) for visualization.

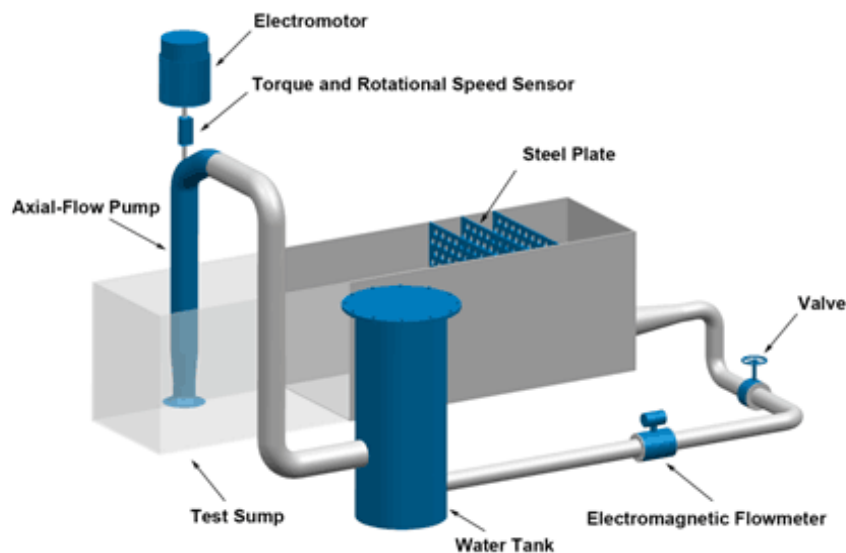


Figure 2. The schematic diagram of the laboratory model.

Figure 3 shows the geometry of the test intake. The inner diameters of the inlet pipe (d) is set as 150 mm, and the diameters of the bell-mouth is 235 mm. The other geometrical parameters (e.g. sidewall clearances (L_1 , L_2), floor clearances (C), backwall clearances (X)) are shown in the table 2. The bell-mouth submergence (S) can be changed by adjusting the water depth in the pump intake.

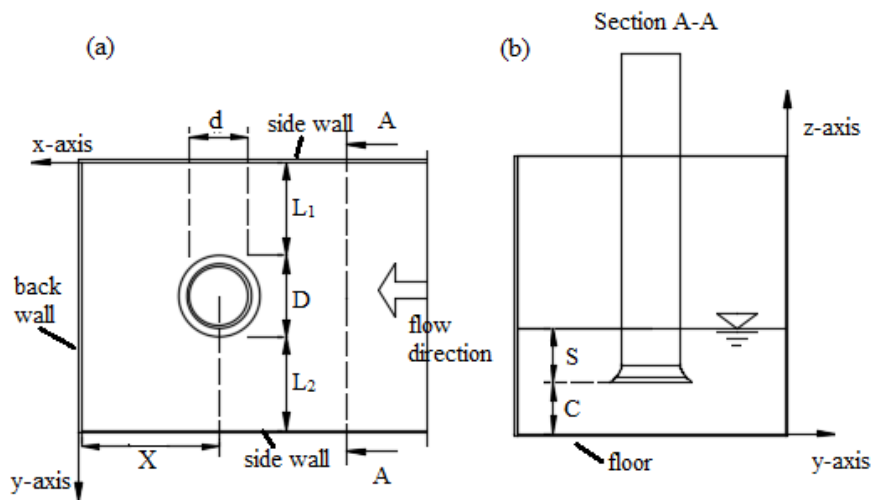


Figure 3. Simplified geometry of pump intake. (a) Plan view and (b) section A-A.

Table 2. Geometrical intake parameters.

D[mm]	D/d	C/d	X/d	L1/d	L2/d
235	1.47	1.0	2.5	2.3	2.3

2.3 Experiment method

In the experiment, the bell-mouth submergence is set as d . The flow rates of the axial pump (Q) is set as $64 \text{ m}^3/\text{h}$ and pump running at 1506 rpm. The improved diversion-cone can be fixed under the bell-mouth by screws and the distance between the improved diversion-cone and bell-mouth can be changed by adjusting the position of the nut on the screws.

At the beginning of the experiment, the pump intake was filled with water to a level which is much higher than the required submergence in this paper. After the axial pump was operated normally, the water was drained from a small opening until the water level reduced to the required submergence. Finally, the water level was kept constant in the intake for a considerable time to provide a required measurement condition. During this period, the camera (SONY PXW-Z150) was used to record the experimental phenomenon. Based on the results from the recording video, the number and position of vortices structure were presented.

For different cone heights and installation heights on the vortices structure, 12 different operating points (OP) of the test intake are listed in table 3. These operating points (OP) assemble from three different types of the improved diversion-cone and four different distances between the diversion-cone and pump bell (h_c) and they are same in flow rates of the axial pump (Q) and submergences of pump bell (S).

Table 3. Operational parameters.

		$Q[m^3/h]$	S/d	h_c
Operating point 1	none	64	1	
Operating point 2	Type 3	64	1	120
Operating point 3	Type 3	64	1	80
Operating point 4	Type 3	64	1	67
Operating point 5	Type 2	64	1	120
Operating point 6	Type 2	64	1	80
Operating point 7	Type 2	64	1	60
Operating point 8	Type 2	64	1	47
Operating point 9	Type 1	64	1	120
Operating point 10	Type 1	64	1	80
Operating point 11	Type 1	64	1	60
Operating point 12	Type 1	64	1	27

3. Results and discussion

Figure 4(a) depicts the typical phenomenon at operating point 12 in which the improved diversion-cone is not employed. An obvious subsurface vortex appears below the bell-mouth and two free surface vortices appear on either side of the inlet pipe.

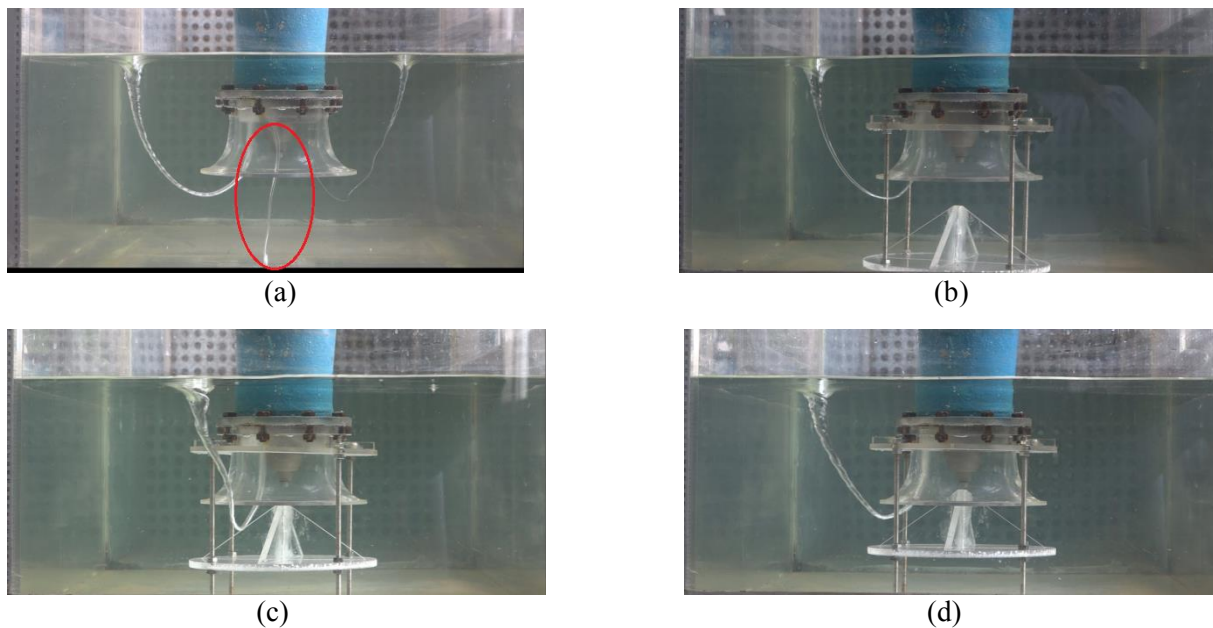


Figure 4. (a) Photograph of operating point 1. (b) Photograph of operating point 2. (c) Photograph of operating point 3. (d) Photograph of operating point 4.

Figure 4(b)-(d) depict the typical phenomenon when the highest improved diversion-cone (Type 3) is employed. The improved diversion-cone is fixed at the bottom of the sump (figure 4 (b)), no subsurface vortex generates in the sump and a continuous free surface vortex from the free surface into bell-mouth is formed. By adjusting the position of the nut on the screws, the distance between the improved diversion-cone and bell-mouth (h_c) is changed. In figure 4 (c), the distance between the improved diversion-cone and bell-mouth (h_c) is set as 80mm and in figure 4 (d), the conic node is closed to the bell-mouth in which the h_c is 67mm. No matter what the height is, no subsurface vortices appear.

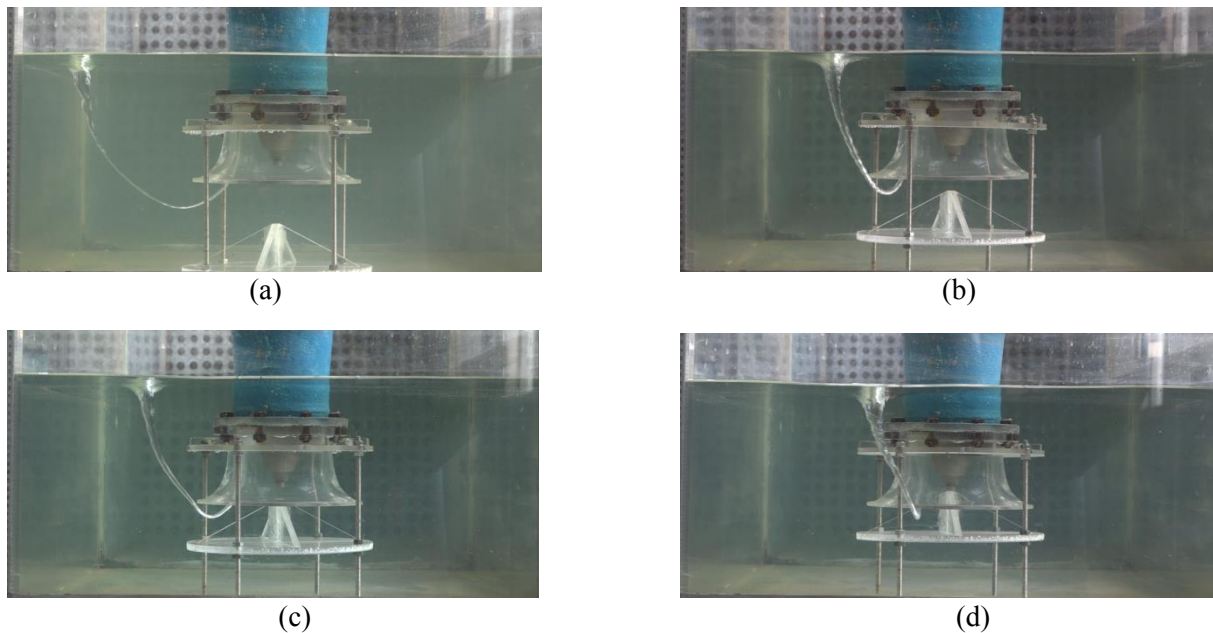


Figure 5. (a) Photograph of operating point 5. (b) Photograph of operating point 6. (c) Photograph of operating point 7. (d) Photograph of operating point 8.

Figure 5 depicts the typical phenomenon when the improved diversion-cone (Type 2) is employed. The height of Type 2 is lower than that of Type 3. When the improved diversion-cone is fixed at the bottom of the sump (figure 5 (a)), no subsurface vortex is formed. Furthermore, the different installation heights of the improved diversion-cone (Type 2) are also studied. The results are shown in the figure 5 (b, c, d) and obviously no subsurface vortex generates.

Figure 6 depicts the typical phenomenon when the lowest improved diversion-cone (Type 1) is employed. The height of the Type 1 is set as 40mm. As is shown in the figure 6 (a), there is no subsurface vortex formed in the sump. At different installation height, the results in the figure 6 (b, c, d) show no subsurface.

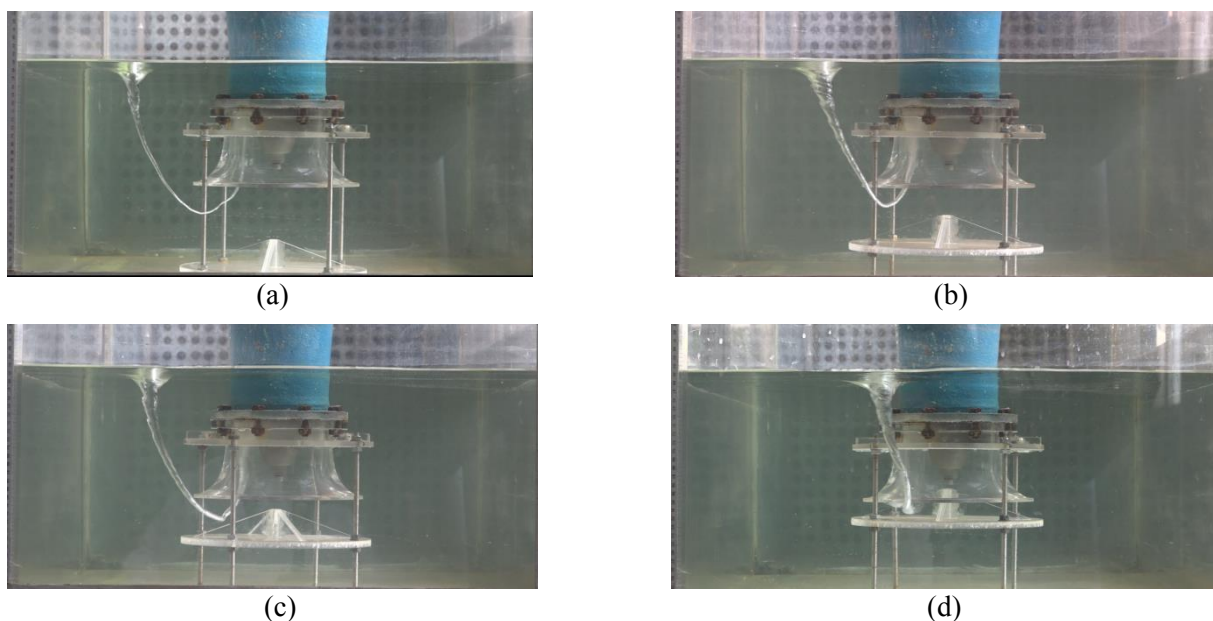


Figure 6. (a) Photograph of operating point 9. (b) Photograph of operating point 10. (c) Photograph of operating point 11. (d) Photograph of operating point 12.

From above, it is found that the improved diversion-cone is effective to suppress the generation of the subsurface vortex whatever the cone height is. And the installation height does not affect its inhibition of the subsurface vortex. Moreover, the improved diversion-cone can be easily installed and adjusted when it is employed on the mobile suction.

The frequencies of the free surface vortex at different operating points are especially studied. The percent of the time length of free surface vortices appear within 10min is set as P . The relation between the percentage (P) and the height (h_c) is described in the figure 7. In the same case of cone type, the percentage (P) gradually increases when height (H_c) decreases, which illustrates that longer of height of diversion-cone (H_c) is propitious to delay the appearance of surface vortices when the distance between the diversion-cone and pump bell (h_c) is adjusted in certain arrangements.

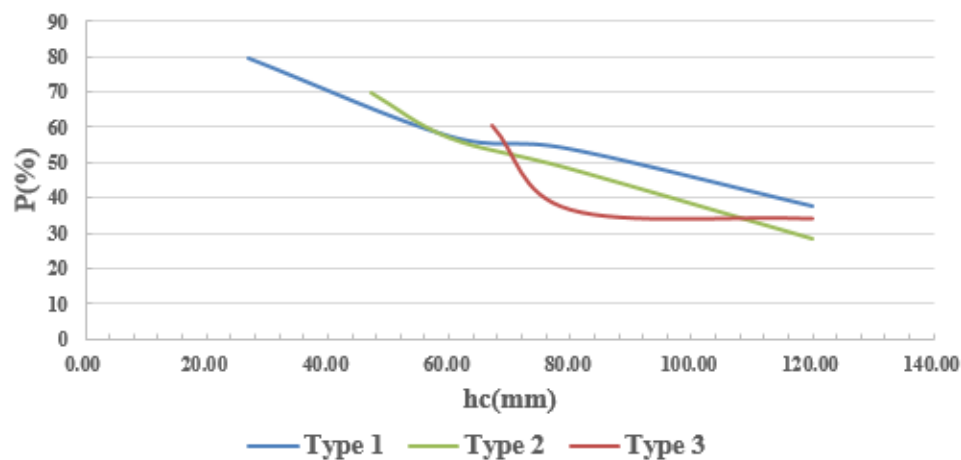


Figure 7. The percentage (P) of the time length at different Operating points.

Meanwhile, in consideration of the surface vortex in sump, our team have proposed a surface vortex-extinction scheme which can be used conjunction with the improved diversion-cone. Through experiments, it was found that there is no surface vortex generating in the test sump, when the surface vortex-extinction scheme was installed correctly. And figure 8 depicts one photograph of the experiment which studied the influence of the scheme on the surface vortex.

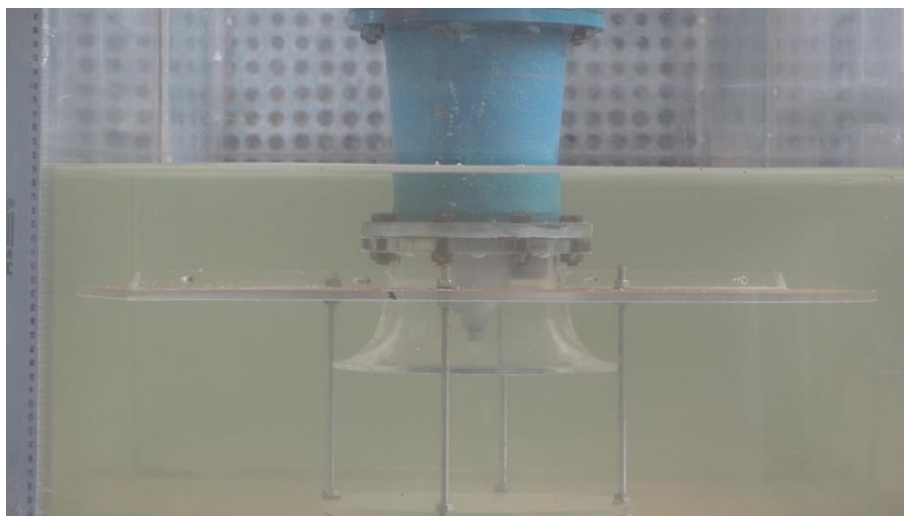


Figure 8. Photograph of experiment.

4. Conclusions

A new improved diversion-cone is employed to suppress the generation of subsurface vortices. From the experimental phenomena with different sizes and locations of the diversion-cone, the improved diversion-cone can be adopted in different incoming flow conditions, which has positive application in engineering.

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