

# The eddy-eliminating method of guide cone in the closed sump

Y J Wang<sup>1</sup>, L Cheng<sup>1</sup>, C Z Xia<sup>1</sup>, J R Zhou<sup>1</sup>, H Q Yan<sup>2</sup>, H Y Jiang<sup>2</sup>

1 School of Hydraulic, Energy and power Engineering

Yangzhou University, Yangzhou, Jiangsu, P.R.China, 225009

2 Jiangsu Water Conservancy Engineering & Technology Consulting Co., Ltd.

Nanjing, Jiangsu, P.R.China, 210029

E-mail: chengli@yzu.edu.cn

**Abstract.** In order to explore the effect on eddy-eliminating method of guide cone in the closed sump, the simple factor analysis and CFD numerical simulation are applied to calculate the flow field of closed sump and select  $\omega$ -shaped back wall.  $\omega$ -shaped back wall is consistent with the stream line in the suction sump, on this basis, CFD numerical simulation is conducted with the eddy-eliminating of the triangle guide cone and traditional guide cone. The results show that, for eddy-eliminating measures, with the height of triangular guide cone from 0 to  $0.407H_z/D_L$ , the excessive triangle guide cone hinder water into the flared pipe. With the width of triangular guide cone from 0.5 to  $1.0B_z/D_L$ , increasing width of triangular guide cone may increase the pumping hydraulic performance and pumping efficiency. However with the width of triangular guide cone from 0.5 to  $1.0B_z/D_L$ , too broad traditional guide cone hinder water into the flared pipe. In the design discharge, whether triangle guide cone or traditional guide cone have a little effect on the efficiency of the pumping station. But in terms of the eddy-eliminating on the bottom of suction sump, it is necessary to set up guide cone.

## Introduction

Suction sump of the pumping station is the role to guide the water from the pumping station forebay into pump impeller, which may ensure water at the suction sump to finish transition and get into the impeller chamber smoothly. Current scholars focused on the hydrodynamic performance analyses, hydraulic efficiency numerical solution, numerical optimization of model test and analyses of eddy-eliminating method with the structure of the pump device. Cheng [1] applied numerical simulation to get the geometry parameters of the open sump. Qian [2] did channel experimental study and got geometry parameters of the open water pumping station. Wang Bencheng [3] used numerical

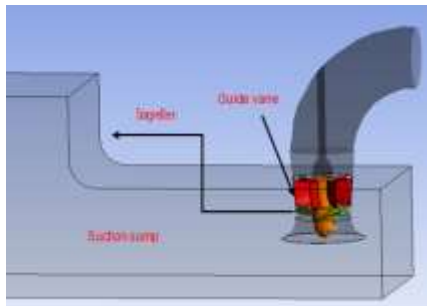
<sup>1</sup> Corresponding author: CHENG Li(1975-), male, PhD, Professor



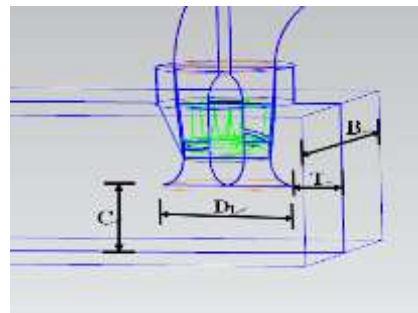
simulation to show the hydrodynamic performance of the bell mouth. Lu Linguang et al. [4] further researched on open sump and completed hydraulic performance optimization. Research on the closed sump is not much and less than the numerical solution and experimental research of box-culvert inlet flow channel [5] ~ [7]. Chen [8] and Zhou [9] did experimental study on the height of the box culvert bell dangling. Yang [10] finished water dynamic characteristics analysis of box culvert type inlet axial flow pump system. Different types and sizes of guide cone are studied on the hydraulic characteristics of the closed sump.

## 2. Calculation model

The closed sump contain suction sump, impeller, guide vane and outlet sump that join with 90o bent pipe. 3D model of vertical axial - flow pump device is shown in Figure 1-1.



**Figure 1-1** 3D model of vertical axial-flow pump device



**Figure 1-2** Geometric parameters of the closed sump

There are three vanes in impeller. The setting angle of the vane is  $0^\circ$ . The impeller diameter is 1200mm. The speed of the impeller is 370rpm. Guide vane there are seven vanes. The design flow rate of the single pump is  $5 \text{ m}^3 \text{ s}^{-1}$ .

Typical closed sump structure is rectangular form. The rear wall shape is rectangle. B represents the width of suction sump. T represents the distance from the rear wall. C represents the height of the speaker tube, which can be shown in Figure1-2.  $D_L$  represents the diameter of speaker tube. The  $D_L$  is 1800mm. The  $D_L$  is used as a basic parameter to indicate the geometric parameters of the closed sump.

## 3. Numerical calculation

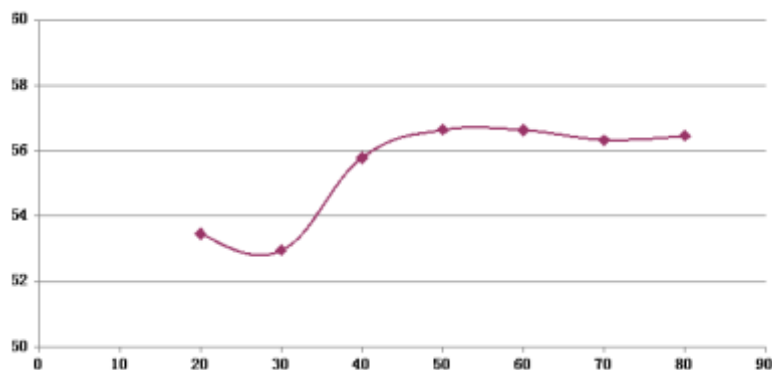
### 3.1 Governing equation

Three-dimensional Reynolds N-S equation is applied to describe in-compressible fluid turbulent flow. The turbulence model is used as standard  $k-\varepsilon$  model. The model by correcting the turbulent viscosity into account the average flow of the rotation and rotational flow, which may deal with high strain rate and streamline the flow of the degree of bend more better.

### 3.2 Boundary conditions and grid meshing

The inlet flow condition is mass flow. The outlet flow is free discharge. The outlet boundary exits the more distant oscula. Due to the pressure or velocity on the boundary are unknown, so the use of free outflows. No-slip conditions be specified in the solid side wall. (Namely  $u = v = w = 0$ ). In the near-wall region of the velocity distribution is determined in accordance with the law of the wall. There is mutual coupling flow existing the interface of suction sump and impeller, the impeller and guide vanes. Dealing the moving and fixed interface play an important influence about computing. The moving and fixed interface with reference system model is adopted to ensure the continuity of the interface.

Taking into account the complexity of the impeller and guide vane, unstructured grid subdivision is adopted. The local grid is refined. Grid-independent verification is completed. Number of grid cells is to 1.9 million. Suction sump is divided 0.6 million grid cells. Impeller is divided 0.21 million grid cells. Guide vanes are divided 0.49 million grid cells. Outlet sump is divided 0.6 million grid cells. Suction sump is conducted grid-independent verification. Grid cells are from 0.2 million to 0.8 million. Efficiency is used as an evaluation Indicators. When number of grid cells from 0.2million to 0.8million, efficiency value exist fluctuation that is from 52.7% to 56.8%. Figure 3-1 indicates that there is a certain number of cells influence on the calculation. Final 0.6 million grid cells is ensured.



**Figure 3-1** Grid-independent verification

## 4. Numerical Simulation and Analysis

### 4.1 Case of guide cone

In order to eliminate eddy on the bottom of the suction sump and research on the impact guide cone of the pump stations hydraulic performance, nine cases are designed (including not add guide cone program). Table 1 is optimized solution for guide cone.  $H_z$  is the height of triangular guide cone.  $B_z$  represents the bottom width of triangular guide cone.

**Table 1** Optimized solution for guide cone

Case Number	$B/D_L$	$T/D_L$	$C/D_L$	Shape of rear wall	Height $H_z/D_L$	Width $B_z/D_L$	Remark
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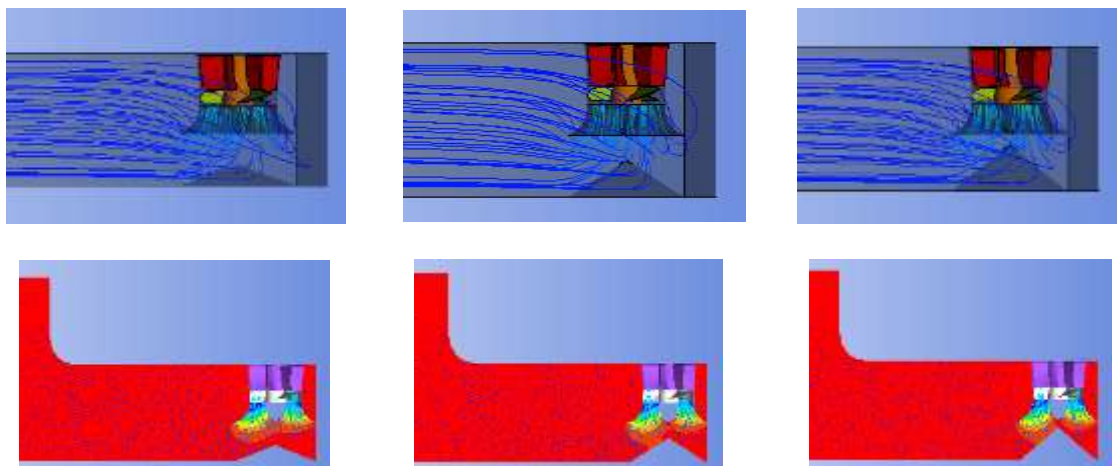
1	2.222	0.278	0.5	$\omega$ shape	0	0	No guide cone
2	2.222	0.278	0.5	$\omega$ shape	0.204	1.0	Triangular guide cone
3	2.222	0.278	0.5	$\omega$ shape	0.305	1.0	Triangular guide cone
4	2.222	0.278	0.5	$\omega$ shape	0.407	1.0	Triangular guide cone
5	2.222	0.278	0.5	$\omega$ shape	0.204	0.5	Triangular guide cone
6	2.222	0.278	0.5	$\omega$ shape	0.204	0.67	Triangular guide cone
7	2.222	0.278	0.5	$\omega$ shape	0	0.5	Traditional guide cone
8	2.222	0.278	0.5	$\omega$ shape	0	0.67	Traditional guide cone
9	2.222	0.278	0.5	$\omega$ shape	0	1.0	Traditional guide cone

#### 4.2 Triangular guide cone

**4.2.1 Height of triangular guide cone** Table 2 is comparative efficiency of different height of triangular guide cone. Table 2 shows that increasing height of triangular guide cone may cause the pumping hydraulic performance degradation, which indicate excessive guide cone to some extent hindered the water into the flare, and affect the detour flow below the flare. Several programs streamline are relatively homogeneous. Contrasting case 4 with case 2, we can find hydraulic performance difference is a smaller and efficiency amplitude is 0.27%. Compared with no add guide cone, hydraulic performance of case 4 decrease amplitude by 0.34%. Contrasting case 2 with case 1, hydraulic performance of case 4 decrease 0.07%. Case 2 to case 4 show that the pressure increase uniformly at the bell mouth, without negative pressure. On terms of the eddy-eliminating in the suction sump bottom of the bell mouth. If select triangular guide cone, case 2 is recommended as preferable case.

**Table 2** Comparative efficiency of triangular guide cone

Case Number	1	2	3	4
Height $H_z/D_L$	0	0.204	0.305	0.407
$\eta$ (%)	56.633	56.560	56.432	56.296



(a) Case 2

**Figure 4-1** Axial pressure distribution of suction sump

(b) Case 3

**Figure 4-2** Axial pressure distribution of suction sump

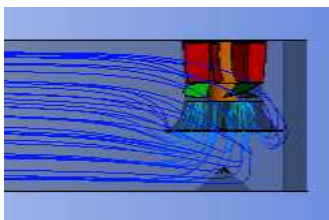
(c) Case 4

**Figure 4-3** Axial pressure distribution of suction sump

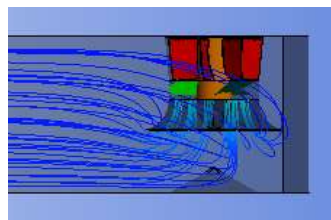
**4.2.2 Width of triangular guide cone** Table 3 shows the efficiency comparison about different width of triangular guide cone bottom. Table 3 shows that increasing width of triangular guide cone may increase the pumping hydraulic performance and pumping efficiency. Hydraulic performance of case 2 decrease amplitude by 0.38%. Too small triangular guide cone bottom width is easy to form a large space below the rear flare leaving excessive retention area, which decrease the pumping efficiency. On the axial pressure surface the velocity vector distribute evenly. Flow velocity evenness is 0.856, 0.823, 0.865. If select triangular guide cone, case 2 is recommended as preferable case.

**Table 3** Comparative efficiency of triangular guide cone

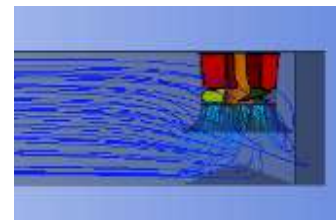
Case Number	5	6	2
Width $B_z/D_L$	0.5	0.67	1.0
$\eta$ (%)	56.176	56.179	56.560



(a) Case 5

**Figure 4-4** Pressure distribution of suction sump exit face

(b) Case 6

**Figure 4-5** Pressure distribution of suction sump exit face

(c) Case 2

**Figure 4-6** Pressure distribution of suction sump exit face

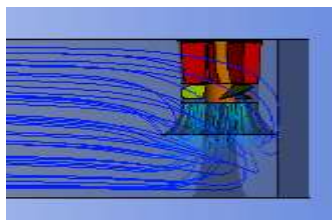
### 4.3 Traditional guide cone

Table 4 is comparative efficiency of different width of traditional guide cone bottom. Table 4 shows that increasing width of triangular guide cone decrease the pumping hydraulic performance and

pumping efficiency, which indicates too broad guide cone to some extent hindered the water into the flare. Contrasting case 9 with case 7, hydraulic performance difference is a smaller and efficiency amplitude is 0.21%. Contrasting case 7 with case 1, pumping efficiency increase 0.04%. On terms of the eddy-eliminating in the suction sump bottom of the bell mouth. Axial pressure distribution of suction sump shows that pressure along the flow direction uniform increments on both sides of the guide cone. If select triangular guide cone, case 7 is recommended as preferable case.

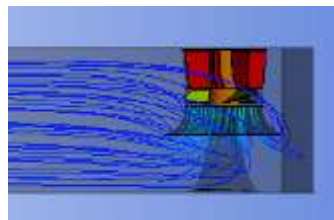
**Table 4** Comparative efficiency of triangular guide cone

Case Number	1	7	8	9
Width $B_z/D_L$	0	0.50	0.67	1.00
$\eta$ (%)	56.633	56.671	56.619	56.429



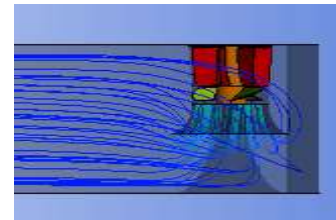
(a) Case 7

**Figure 4-7** Axial pressure distribution of suction sump



(b) Case 8

**Figure 4-8** Axial pressure distribution of suction sump



(c) Case 9

**Figure 4-9** Axial pressure distribution of suction sump

## 5. Conclusions

On terms of triangular guide cone, increasing height of triangular guide cone may cause the pumping hydraulic performance degradation, which indicates excessive guide cone to some extent hindered the water into the flare, and affect the detour flow below the flare. And as the growth of triangular guide cone's width, it may increase the pumping hydraulic performance and pumping efficiency, which indicates increasing width of triangular guide cone may guide water into the flare.

On terms of traditional guide cone, increasing width of triangular guide cone decrease the pumping hydraulic performance and pumping efficiency, which indicates too broad guide cone to some extent hindered the water into the flare.

Whether select triangular guide cone or traditional guide cone, on terms of pumping efficiency, guide cone have not great effect. However in terms of the eddy-eliminating on the bottom of suction sump, it is necessary to set up guide cone.

### Acknowledgments

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