Investigation on Flow Air Concentration Effect on Distance of the Chute Spillway Aerators

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ABSTRACT

Flow aeration using aeration systems has been used as one of the most effective methods to prevent the occurrence of cavitation. Today, access to equipped computers and software based on computational fluid dynamics caused increasing use of numerical simulations in current analysis. In this research, Flow-3D software was used to simulate flow through the spillway aerator of chute. To validate the results of a numerical model in which the criterion was the air concentration in the aerator downstream, laboratory data of other researchers are used and the results indicate that they are in good agreement with the laboratory data. The effect of geometric parameters on the changes in air concentration, flow characteristics such as velocity and pressure to determine the cavitation index in order to determine distance between two aerators were explained. The average air concentration is as layer changes in the depth of flow and the reduction of air concentration is as exponential function. The value of the cavitation index is greater than the critical value during 11 meters after aerator in the chute spillway and there is no risk of cavitation occurrence. Considering the calculated concentrations, it can generally be concluded that by decreasing the air concentration in the chute bed to the values of 0.0001, 0.001, 0.01 and 0.1, chutes with slopes of 10, 12, 30 and 50 degrees do not require more aeration, respectively.

KEYWORDS

Aerator, Two-Fluid Flow, Computational fluid dynamics, Chute spillway Cavitation.

1. Introduction

Chute spillway as one of the important hydraulic structures of the dam, used to control the water level during large floods to protect the dam from overflow. Between 1960 and 1980s, several significant overflow damages were observed. Degradation of concrete surfaces and foundations was found, especially in high-velocity areas due to cavitation. Most spillways are equipped with aerators to protect against cavitation damage [1].

In an aerator, the high-velocity water flow on the spillway chute is diverted by a ramp and step. Chute aerators separate the flow from the bottom of the chute. In the cavity zone, air is introduced from the atmosphere through the air duct and entrained into the flow because of high-turbulence eddies close to the air–water interfaces. The air is then transported downstream of the chute aerators [2]. The air has reduced the negative pressure near the bottom of the chute and as a result, cavitation is prevented [3]. Hence, information on how the air concentration is distributed and the cavitation index during the spillway to determine the appropriate distance of the aerators from each other and supply minimum air concentration is important to prevent cavitation damage and in this article, this issue is examined.

2. Methodology

Flow-3D Software uses the limited volume in the rectangular regular netting to stimulate aerated flow. To model the weather as two different phases not only the air entertainment, surface tension, density evaluation, but also drift-flux model are used in the software. In the drift-flux model, weather bubbles can move in the water due to their density differences, while can egress from the free surface. Therefore, it calculates and saves the value model as the volume part of air entertainment.

Four block meshes are in the coordinates system to chute model. The meshes are in despondently defined in the three perpendicular aspects. The square cells are tested to evaluate not sensibility with aspects 2, 1.5, 1 and 0.8 centimeter with almost number 15745, 20571, 25486 and 49262 respectively. Figure.1 shows a comparison between stimulation results in the proportion to the mentioned cells for the entertainment with the stair height 100 mm, slap ramp 8.1 degree and height 13.3 mm of ramp according on the chute with slap 30 degree. The sensitiveness try of net is done to reach the stable results without change. Netting with cells 1 cm proposes the nearest results to the lab models. Based on the software help, the turbulent model is used for the model option of the air entertainment using RNG.

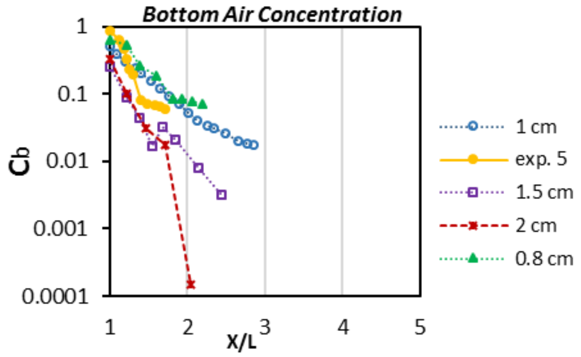

Figure 1. Sensitivity to different cell dimensions

3. Results & Discussion

To validate the results of a numerical model, Hager and Pfister (2010) laboratory data are used and the results indicate that they are in good agreement with the laboratory data.

σ is cavitation index, P_0(N/m^2) is the fluid piezometric pressure and the atmosphere pressure, P_v(N/m^2) is water stream pressure, ρ(kg/m^3) is fluid density, u(m/s) is fluid mean speed. According to USBR, the proposed more than 0.25, which is not les to Cavitation[4]. The following are the sensitization results of the flow cavitation index to the geometric parameters of the aerator.

In this study, by pressing the pressure in the points of the chute bottom, the cavitation index is obtained from Equation (1).

$$\sigma = \frac{P_0 - P_v}{\frac{1}{2}\rho u^2} \qquad (1)$$

Figure 2, for the air entertainments with scale 8.1 of ramp, cavitation indicator in the point of Confrontation of jet with chute bed and the second zone under the air entertaining Conditions with the stair 45 mm, shows the maximum value, while the minimum value for the stair 100 mm, in this zone also cavitation index procedure is under effect of speed changes. In the third zone also, the cavitation index reduces as the stair height increases, showing as the stair height increases, the amount of air output and speed increases leading the pressure reduction. The performance of entertainer was better without stair condition. Hence, the trend of cavitation index changes in the length of chute for the different slap of ramp include 4.86, 6.48, 8.1, 9.7 and 11.3 in proportion to the ramp height changes equals 13.3, 7.98, 10.64, 15.96 and 18.62 mm, while the stair height and the stair height changes equals 100, 45 and zero which are evaluated.

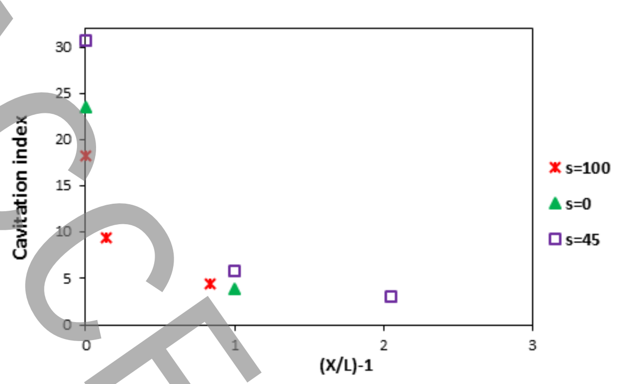

Fig. 2. Flow Cavitation index - chute angle:30 - Ramp angle: α=8.1

4. Conclusion

- The amount of cavitation index and its changes trend in length 11 meter after air entertainment on the spillway chute are evaluated, while the danger of the cavitation occurrence wasn't observed. Regarding to the amount of calculated concentration, it must be concluded as the air concentration reduces in the chute bed until the value 0.0001, 0.001, 0.01 and 0.1 that no second air aerator is needed. The speed, pressure and air exit is the effective parameters on the amount of cavitation. It is mentioned the effect of speed on the cavitation index is more than other parameters. The trend of cavitation index changes as the stair height increases and the ramp height as well ramp slap is in proportion speed changes trend.

- It is also observed as slap and height of ramp increases the stair height and the amount of the air output, while the slap chute increases as the amount of air output decrease.

- The trend of speed and pressure changes is affected by the entry and exit of air.

5. References

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