

Experiment research on water noise of the rubber dam

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Abstract. In order to study the relationship between the water noise of the rubber dam and the different hydraulic conditions including the different discharge and the plunge pool conditions, this paper proposes the detailed analysis supported by the model test. Besides, the tail ridge and the length are also considered, respectively. A number of noise measurement points with 10cm spacing are arranged along the length, width and height of the plunge pool in the downstream of the rubber dam model. The noise of different measuring points in different conditions is measured and analyzed by using the noise spectrum analyzer. The results show that while the flow and the plunge pool length are the same, the water noise decreases with the tail ridge height increasing; while the flow and the height of the plunge pool tail ridge are the same, the water noise decreases with the length of the plunge pool increasing; while the length of the plunge pool and the height of the plunge pool tail ridge are the same, the water noise increases with flow increasing.

1. Introduction

Nowadays, air pollution, water pollution and noise pollution are the three major pollutions of human beings. People pay more attention to noise pollution when the concerns of air pollution and water pollution are still rising at the same time, because noise pollution problem is more and more serious in our daily life, especially the airport noise and the cooling tower noise. Generally, the noise is divided generalized noise and narrow noise, the generalized noise refers to that noise hinder the people to receive the sound outside of all the background sound. It is a very complex concept. Nevertheless, the sound from the source is called the narrow noise. Although there are different definitions about the noise, it also affects people's normal daily life on physical and psychological damage. Currently, the research on noise forms systematic theory about the mechanical and construction noise, and the underwater acoustic science researches mainly focus on ships, underwater navigation and military, because most of the water conservancy projects are far away from the cities, noise generated by outlet structures has failed to arouse people's attention.

Timouchev and Tourret^[1] pointed out that the vibration and noise level of the centrifugal pump were closely related to the pressure fluctuation in the cavity which increased with the increase of the speed and power. Srivastav^[2] studied the influence of the clearance rate between the tongue and the impeller of the centrifugal pump on the vibration and noise. Benra^[3] combined computational fluid dynamics with structural finite element analysis method, and the unsteady numerical simulation method was used to calculate the internal flow field and rotor vibration of the centrifugal pump. Langthjem and Olhoff^[4-5] used numerical simulation to calculate two-dimensional flow induced noise, the calculated result was in agreement with the experimental results. Wu^[6] conducted a preliminary study on low noise marine pump and analyzed the impact of the main geometric parameters of the



pump on the vibration and noise, and proposed the optimization scheme of a model pump. Zhu et al^[7] studied the effect of the pump vane on the hydrodynamic characteristics and proposed the analysis method of fluid viscous flow on the surface of the blade, which found that serious flow separation would reduce the performance of the pump and increase vibration and noise. Huang et al^[8] studied the effects of impeller blade length of design points on centrifugal pump pressure pulsation and flow noise through FLUENT numerical simulation software, the calculation results showed that the structure of short blade can effectively reduce the flow noise. Wang et al^[9-10] studied the effect of structural vibration on the acoustic radiation of the axial flow pump through numerical simulation method. The numerical simulation results showed that the external sound field of the pump had the characteristics of the dipole noise.

To sum up, there are many researches on the noise of water conservancy engineering, but the literatures about the theory of system noise on the spillway discharge flow remains to be perfect. This paper mainly studies the water noise of the rubber dam when the water discharging into the plunge pool. Rubber dam is a common hydraulic structure and the downstream of it usually links to energy dissipation facilities.

2. Model test

2.1. Test model setup

The whole water supply system is composed of two water tanks, and the water tanks are made of polyethylene plates. The above water tank provides a constant steady current for the whole basin while the below one is a storage tank which can both supply water for the water tank and receive water from the basin. The whole experiment equipment is completed in the self circulating sink. The self circulating water tank is made of 0.5cm thick organic glass plate, with width 50cm and middle axis length 1071cm. The specific experimental sink is shown in Fig.1 (a).

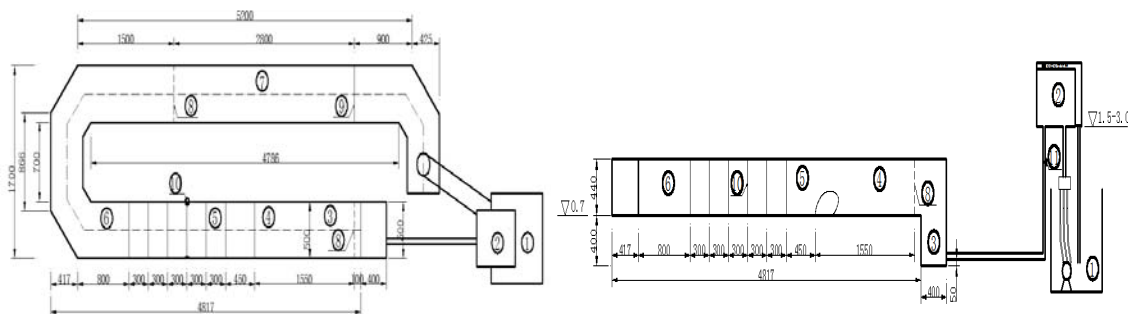


Fig.1 (a) The plan of the experimental sink [mm] (b) The sectional view of the experimental sink [mm]

Water noise measurement is conducted on the section of plunge pool, which is 90 cm long and there is a slot every 30 cm. The state of flow in the plunge pool varies by adjusting the plunge pool length and tail ridge height, which also controls the downstream water level. The details are shown in Fig.1 (b).

2.2. Test model program

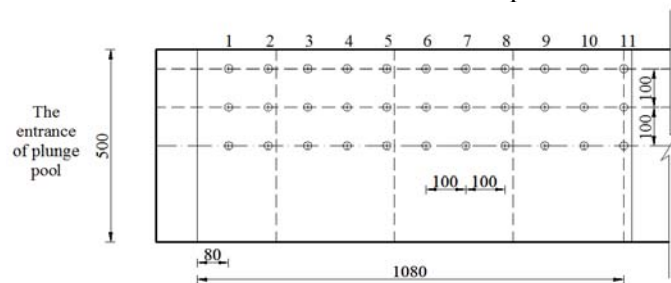
The experiment tests the water noise under three kinds of discharge, tail ridge height and length of the plunge pool. Three kinds of flow: $Q_1=4.8\text{Ls}^{-1}$, $Q_2=5.9\text{Ls}^{-1}$, $Q_3=8\text{Ls}^{-1}$ (while the tail ridge height is 3cm, the plunge pool length is 30cm); three kinds of tail ridge height: $H_1=1.0\text{cm}$, $H_2=2.0\text{cm}$, $H_3=3.0\text{cm}$ (while the discharge is 4.8Ls^{-1} , the plunge pool length is 30cm); three kinds of plunge pool: $L_1=30.0\text{cm}$, $L_2=60.0\text{cm}$, $L_3=90.0\text{cm}$ (while the discharge is 8.0Ls^{-1} , the tail ridge height is 3cm). The experiment conditions are shown in Table.1. X_{ijk} indicates the working conditions-flow Q_i , plunge pool length L_j , tail ridge height L_k .

Table.1 The classification of Water noise data analysis

Weir Type	Condition number	Discharge (Ls^{-1})	Plunge Pool Length (cm)	Tail Ridge Height (cm)
Rubber Dam	X111	4.8	30.0	1.0
	X112	4.8	30.0	2.0
	X113	4.8	30.0	3.0
	X213	5.9	30.0	3.0
	X313	8.0	30.0	3.0
	X323	8.0	60.0	3.0
	X333	8.0	90.0	3.0

2.3. Arrangement of measuring points

The arrangement of noise measuring points in plunge pool is shown in Fig.2. Arranging measuring points in this way can reduce a large number of repeated measurement data because the flow patterns in the left-right side of the tank axis are the same. Besides, arranging measuring points in different locations and heights of the rubber dam downstream can accurately measure the noise of its downstream water. Both the points of row and column distance are all 10cm, noise measuring points are arranged three heights above the water which are 10cm, 15cm and 20cm, respectively. Furthermore, the noise measurement points are analyzed according to the arrangement order of the points, such as No. 2 point mentioned refers to the 2 measurement point in the cross-section data.

**Fig.2** Pressure points plan of the Stilling basin [mm]

2.4. Main contents of experiment

The main instruments used in the experiment are: the triangular weir which is used for measuring the discharge; the ruler (the precision is 1mm) which is used for measuring the water level; the *LS-501D* direct reading type propeller current meter (Fig.3) which is used for measuring the flow velocity; the ZonicBook/618 professional vibration and noise analysis system (Fig.4) which is used for measuring the water noise.

**Fig.3** LS-501D Direct reading meter**Fig. 4** ZonicBook/618 professional vibration system

3. Results and discussion

3.1. The impact of the water noise value in the plunge pool with the tail ridge height changing

This part takes working conditions X111, X112, X113 as the object of discussion. They all have the same upstream flow- 4.8Ls^{-1} , the same plunge pool length-30cm, but the plunge pool tail ridge heights are 1cm, 2cm, 3cm, respectively.

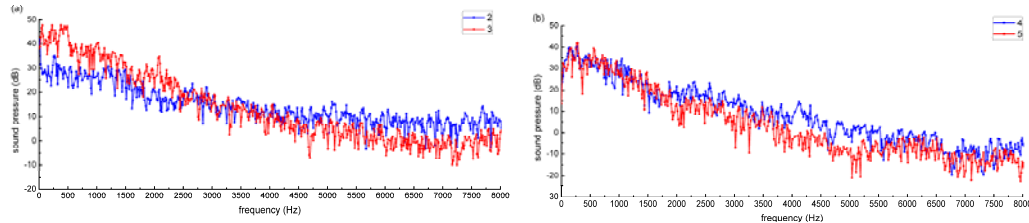


Fig.5 Noise spectrum of program X111 (a) NO.2,3 point; (b) NO.4,5 point

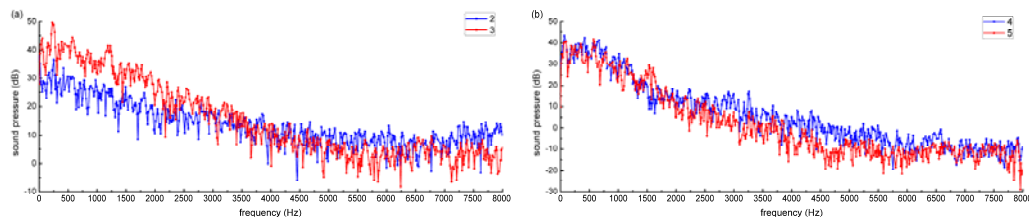


Fig.6 Noise spectrum of program X112 (a) NO.2,3 point; (b) NO.4,5 point

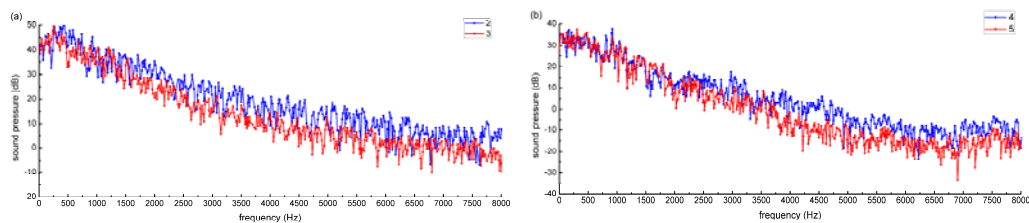


Fig.7 Noise spectrum of program X113 (a) NO.2,3 point; (b) NO.4,5 point

From the Figs.5, 6 and 7, the conditions of noise spectrum are similar in shape from the view of the entire spectrum change trend. The sound pressure value decreases with frequency increasing and main frequency are located within 1000Hz. Sound pressure value declines sharply and acoustic energy reduces cross main frequency. The sound pressure level is decreasing, low frequency region is the high energy region and the sound pressure value is higher; the high frequency region is the low energy region and the sound pressure value is lower. Thus the acoustic energy is in the loss along the way. The change of tail ridge height will affect noise values-the water noise increases with the tail ridge height reducing while the flow and the plunge pool length are the same. The maximum value is located at No.2 point under the same working condition and the trend of the sound pressure value changing with frequency is consistent.

3.2. The impact of the water noise value in the plunge pool with the plunge pool length changing

This part takes working conditions X313, X323, X333 as the object of discussion. They all have the same upstream flow- 8Ls^{-1} , the same plunge pool tail ridge height-3cm, plunge pool lengths are 30cm, 60cm, 90cm, respectively.

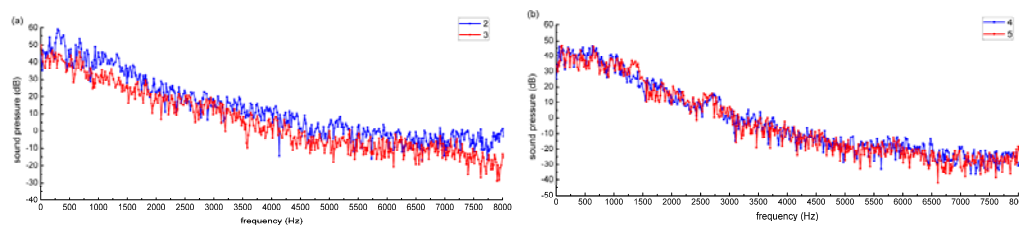


Fig.8 Noise spectrum of program X313 (a) NO.2,3 point; (b) NO.4,5 point

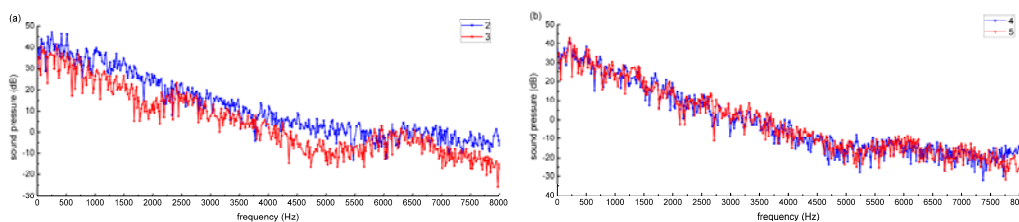


Fig.9 Noise spectrum of program X323 (a) NO.2,3 point; (b) NO.4,5 point;

From Figs.8 and 9, it is found that when working condition is X313, the variation amplitude of sound pressure level is mainly between 30dB and 45dB, the pressure value reaches at 52~60 dB at three peaks and the pressure value of 352Hz is 55dB; when working condition is X323, the variation amplitude of sound pressure level is mainly between 20dB and 40dB, the pressure value reaches at 40~47dB at four peaks and the pressure value of 250Hz is 47dB; when working condition is X333, the variation amplitude of sound pressure level is mainly between 30 and 40dB, the pressure value reaches 45dB at one peak and the maximum value is at 300Hz. Therefore, the sound pressure level is the overall declining with the rubber dam plunge pool length growing.

4. Conclusions

This paper studies the water noise characteristics of low water head and velocity water conservancy project and takes the plunge pool as the research object. And then systematically analyzes the water noise of the plunge pool downstream of the rubber dam by means of model test and spectrum analysis, and the conclusions are as follows:

- The tail ridge height changes will affect noise values while the flow and the plunge pool length are the same. The water noise increases with the tail ridge height reducing and the maximum value is located at No.2 points under the same working condition, besides the sound pressure value reduces with frequency increasing.
- The water noise of the rubber dam reduces with the plunge pool length growing, while the upstream flow and the plunge pool tail ridge height are the same.
- The sound pressure value increases with the flow increasing while the plunge pool length and the plunge pool tail ridge height are the same. Besides, the maximum value is located at No.2 points on cross section and the rest of the values of measuring points have less change with frequency changing.

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