SUBATMOSPHERIC HYDRAULIC MODEL TEST ON BOTTOM OUTLET FOR HIGH-WATER-HEAD

XI-BIN HUANG [1] and JIA-CAI LI [2]

[1]Senior Engineer, College of water conservancy and hydropower engineering,
Hohai University, Nanjing 210098, China
(Tel: +86-25-86082958, e-mail: xbhuang@hhu.edu.cn)
[2]Engineer, College of water conservancy and hydropower engineering,
Hohai University, Nanjing 210098, China

The bottom outlet of flood-discharge tunnel is the lowest sluicing structure in Jilintai hydroelectric project, China. There are a flat sliding maintenance gate (4m×7m) and an arc service gate (4m×5m) in the bottom outlet, whose design water head are both 80m. The aim of subatmospheric hydraulic model test is to verify the performance of the designed gate groove to resist cavitations, to analyze gate groove's characteristics of cavitation and the law of variation, to apply special noise detecting apparatus and high speed data acquisition and analyzing system to record and analyze the hydraulic condition of incipient cavitation.

The model is geometrically undistorted one following the similarity criterion of the gravity to design (Zuo, 1984). We choose the length scale $\alpha_l = 26$, and the other corresponding scales can be derived as well. As for the subatmospheric model, except for meeting the gravity similarity criterion, its cavitations number should be equal to the prototype's cavitations number. Because of pressure reduction in the vacuum tank, the air content in water is released, which increases the water's tension strength, so the vacuum η in the tank should be a little larger than needed. The whole noise detecting and analyzing apparatus is composed of hydrophones, magnifier, filter, high speed data acquisition equipment and computer and so on.

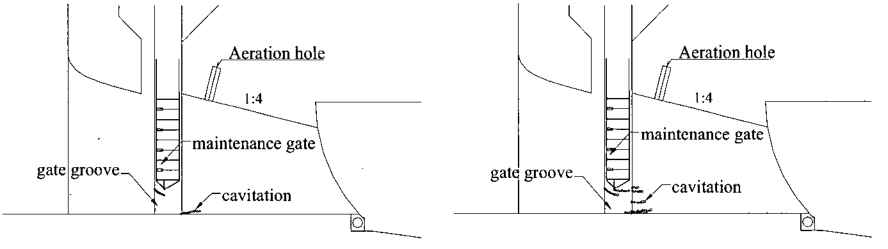
The test results show that under maintenance gate opened completely, whether the service gate is opened completely or partially, wherever the water level is, there is no cavitation characteristic in the noise spectrum.

Under the maintenance gate opened partially, when the opening is 10%, 20%, 30%, the incipient cavitation and stronger cavitation appears near the gate groove with the vacuum η increasing in tank. Fig. 1 is the exhibition of incipient cavitation and stronger cavitation observed by sight. Based on the experiment data, the incipient cavitation number can be got as follows:

$$\sigma_i = \frac{p_{am} + p_{1m} - p_{vm}}{\rho V_m^{\,2} / 2} = 2.33 \tag{1}$$

where, p_{am} is the air pressure in the vacuum tank; p_{1m} is the pressure of model on reference point 1; p_{vm} is the saturated vapor's pressure of model; V_m is the mean velocity of model at reference section.

When cavitation number $\sigma \le \sigma_i$, cavitation appear. It shows that under the condition of the maintenance gate opened partially, the flow incipient cavitation number is far bigger than one under the condition of maintenance gate opened completely. The reason is that when the gate is opened partially, the high velocity flow escapes from the border, shearing the flow near the gate groove and form so strong swirl in the shear layer that its center is subatmospheric and cause cavitation. The cavitation region spreads to the downstream reaches and meets the higher pressure region on the sidewall where the bubbles collapse and form strong pressure accompanied with noise. So it must be noticed that the process of open and close of maintenance gate should not last too long, and the gate only can be opened or closed completely for high-water-head, or it will cause cavitation damage to the gate and gate groove.



(a) Incipient cavitation (b) Stronger cavitation

Fig. 1 Diagrammatic sketch of cavitations under maintenance gate opened partially.

REFERENCES

The Ministry of Water Resources of People's Republic of China, 1995. Test Regulations for Models of Flow's Cavitation (SL156—95). Beijing: Water Conservancy and Hydroelectric Power Publisher, pp. 1-6. (in Chinese)

Zuo, D.Q., 1984. Theory and Method of Model Test. Beijing: Water Conservancy and Hydroelectric Power Publisher, pp. 197-200. (in Chinese)