Study on Comprehensive Hazard Assessment Technology of Flood Discharge Atomization of Jinping Hydropower Station

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Abstract. At present, the research on the flood discharge atomization of high dam mainly focuses on the partition and prediction of the affected area, while the comprehensive assessment of the hazard degree and the environmental impact degree of atomization around the dam having little achievement. In this paper, an evaluation model of flood discharge atomization based on fuzzy mathematics-hierarchical analysis is constructed. The coupling relationship between fuzzy mathematics analysis module and hierarchical structure analysis module is established through the evaluation results of hazard degree of atomization. The hazard degree of flood discharge atomization and the degree of engineering safety and local environmental impact are synthetic evaluated in Jinping Hydropower Station.

Introduction

At present, China has successively designed and constructed a number of large-scale hydropower projects with high dams and super-high dams of nearly 300 meters or over 300 meters. These projects have the common characteristics of "high head, large discharge, narrow valley", and their flood discharge and energy dissipation are one of the key technical problems of the project\(^{[1-3]}\).

Relying on a series of physical models, such as Wujiangdu (dam height 165.0m, scale 1:35, 1:60, 1:80, 1:100), Ertan (dam height 240.0m, scale 1:25, 1:35), Jinping I (dam height 305.0m, scale 1:50), Nanjing Hydraulic Research Institute has made a thorough study on the atomization similarity of model test\(^{[4-6]}\). The numerical simulation analysis of flood discharge atomization of Baihetan, Ertan, Lianghekou and Xulong high arch dam hydropower stations was carried out by the Chinese Institute of Water Resources and Hydropower Research, Tianjin University and Changjiang River Scientific Research Institute\(^{[7-13]}\). However, the establishment of comprehensive impact assessment model for engineering safety and local environment of atomization has not been discussed in detail.

In this paper, the method of combining fuzzy mathematics with analytic hierarchy process (AHP) model is used to evaluate comprehensively the environmental impact of Jinping Hydropower Station. To solve the problem that it is impossible to assess the environmental impact of flood discharge atomization by using the basic data.

Assessment Index System for Environmental Impact of Atomization in High Dam Factor Set and Fuzzy Mathematics-Hierarchical Model

In order to evaluate the comprehensive impact of atomization on environment of high dam flood discharge, it is necessary to evaluate the atomization degree of the project itself first. The set of factors can be divided into the set of factors for evaluating the hazard degree of atomization and the set of factors for evaluating the environmental impact of atomization.

According to the selection criteria of evaluation factor set, the hierarchical structure model of comprehensive evaluation of flood discharge atomization is established. As shown in Figure 1. From top to bottom, there is the target layer, the criterion layer and the scheme layer in the hierarchical
structure model. The evaluation target is the environmental impact degree of flood discharge atomization, and the criterion layer is the evaluation factor set of atomization hazard degree.

**Target layer**

![Hierarchical structure model for comprehensive assessment of environmental impact on flood discharge atomization](image)

**Evaluation Set**

Assessment sets are generally divided into five levels: "great harm", "more harmful", "Not much harm", "Less harmful" and "no harm".

**Assessment Index System for Environmental Impact of Atomization in High Dam**

Jingping Hydropower Station is a large-scale project with Concrete Double-Curvature Arch Dam with a maximum dam height of 305.0m; flood discharge and energy dissipation are dominated by dam body. The designed discharge of the dam body is 9069.0m³/s, and the discharge is huge.

Three working conditions are selected for evaluating the atomization degree of flood discharge, including surface hole, deep hole combined flood discharge and surface hole and deep hole separate flood discharge. The specific parameters are shown in Table 1.

**Table 1. Test conditions and opening mode table of Jingping hydropower station.**

| Working condition | Characteristic flood | Water level difference [m] | Discharge volume [m³/s] | Opening Mode | Water entry angle | Depth of water cushion [m] |
|-------------------|----------------------|-----------------------------|-------------------------|--------------|------------------|--------------------------|
|                   |                      |                             | Surface hole            | Deep hole    | Total            |                          |
| 1                 | Design 0.1%          | 219.93                      | 3675                    | 5394         | 9069             | 4 Surface +5             |
|                   |                      |                             |                         |              |                  |                          |
| 2                 | Frequent (1)         | 225.28                      | 0                       | 5454         | 5454             | 5 Deep                   |
| 3                 | Frequent (2)         | 229                         | 2681                    | 0            | 2681             | 4 Surface                |

**Assessment of Hazard Degree of Atomization**

According to the characteristics of flood discharge atomization factors, it can be divided into quantifiable factors and non-quantifiable factors.
Quantifiable Factors. According to the probability density function of quantifiable factors such as water head, discharge volume, water entry angle, and Depth of water cushion \((u_1-u_4)\), the membership function curve of the probability density function is transformed as shown in Figure 2.

![Figure 2. Membership function curve corresponding to quantifiable factors.](image)

Non-quantifiable Factors

Table 2. The value of discontinuous membership function corresponding to non-quantifiable factors.

| Evaluation set | Factor value Classification | \(u_5\) | \(u_6\) | \(u_7\) | \(u_8\) | \(u_9\) | \(u_{10}\) | \(u_{11}\) |
|----------------|-----------------------------|-------|-------|-------|-------|-------|-------|-------|
| \(v_1\) | \(v_2\) | \(v_3\) | \(v_4\) | \(v_5\) | RAH | L/B | \(\beta[^\circ]\) | \(V[m/s]\) | \(\Omega[^\circ]\) | \(T[^\circ]\) |
| 0 | 0.1 | 0.4 | 0.6 | 0.4 | 1 | Surface only(1) | 20 | 3.2 | 30 | 3 | 180 | 0 |
| 0 | 0.2 | 0.6 | 0.4 | 0.2 | 2 | Deep only(2) | 15 | 2.7 | 50 | 4.5 | 135 | -8 |
| 0.2 | 0.4 | 0.8 | 0.2 | 0 | 3 | Upper and Down Collision (3) | 10 | 2.3 | 60 | 7.5 | 90 | -15 |
| 0.4 | 0.6 | 0.4 | 0.2 | 0 | 4 | Upper and Down Collision plus Horizontal hedge (4) | 5 | 2 | 70 | 9 | 45 | -20 |

According to the principle of maximum membership degree, it is concluded that the evaluation result of working condition 1 is "more harmful", while that of working condition 2 and 3 is "less harmful". The flow rate of working condition 1 is obviously larger than that of other two working conditions. The collision energy dissipation of surface and deep holes leads to a sharp increase in hazards of atomization.

Assessment of Engineering Safety and Local Environmental Impact of Atomization

Referring to the existing engineering atomization data, the correlation degree between the criterion layer and the secondary classification factors is assigned, and the correlation diagram is drawn. As shown in Figure 3, the red line in the diagram indicates a high correlation degree (correlation value is 5-10), the grey line indicates a medium correlation degree (correlation value is 3-4), and the other undrawn ones show a low correlation degree (correlation value is 1-2).

By multiplying the weight vector of criterion layer and the weight matrix of scheme layer, the total ranking score of engineering safety and local environmental impact of atomization can be obtained as follows:

\[ A = (0.84, 1.25, 1.10) \]
By summing up the scores of each factor in the hierarchical structure, the comprehensive evaluation score of the environmental impact degree of flood discharge atomization of Jingping Hydropower Station is 2.85, and the evaluation result is "more harmful". Among them, the stability of bank slope is most affected by flood discharge atomization, and the operation of power station is least affected by flood discharge atomization. According to the results of flood discharge atomization test and comprehensive environmental impact assessment, the safety protection of atomization in reservoir area should mainly focus on the stability of the slope on both sides of the power station, such as concrete slope protection, construction of drainage facilities and removal of rubble.

Figure 3. Schematic diagram of correlation degree between criterion level factors and scheme level two-level classification factors.

Summary
This paper takes 300m high arch dam just like Jingping Hydropower Station as the research object, and establishes a relatively perfect evaluation index system of the atomization environmental impact on high dam based on fuzzy mathematic-hierarchical model. This model Constructs the influence degree of scheme layer affected by the target layer and the weight matrix through the correlation degree between the scheme layer and the criterion layer. A set of comprehensive evaluation method for the impact of atomization on environment of spillway discharge in high dam is established. The results show that the hazard degree of atomization of Jingping Hydropower Station are "more harmful"; the engineering safety and local environmental impact degree of atomization of Jingping Hydropower Station are "more harmful", and the stability of bank slope is most affected by flood discharge atomization.

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