ISSN:2790-1688 DOI: 10.56028/aetr.3.1.762

Brief Discussion on the Application of the New Melting-Deicing Device (MDD) on the Flap Gate of the Yitong River

Yehan Geng[1,a], Kaixuan Li[1], Zhan Wang[1], and Yongsheng Yan[1]

[1]China Institute of Water Resources and Hydropower Research, Beijing, China

[a] gyh916@126.com

Abstract. In order to solve the winter operation problem of the flap gate of the Yitong River in Jilin Province, 4 sets of new Melting-Deicing Devices(MDD) were arranged in front of the flat gate, and the prototype observation research were carried out as well. The analysis results showed that MDD mixed compressed air into the water body during its work so that micro-nano bubbles were formed, and then the water body mixed with bubbles was pushed out and diffused horizontally under the drive of the motor, which had a high disturbance ability to the water body, and could realize the heat exchange between the bottom water body and the surface water body, thereby having an ice-thawing effect on the frozen layer, and effectively reducing the generation rate of ice nucleus in the water for the unfrozen water body, thus avoiding the generation of ice flowers and preventing the freezing of the water surface.

Keywords: Melting-Deicing Device; winter operation; gate; heat exchange; ice nucleus

1. Introduction

The Yitong River is a left-bank tributary of the Yinma River system in the Songhua River Basin, originating from the northwest side of Daqingdingzi Mountain, Dajianggang Village, Shimiao Township, in the southeast of Yitong County, Jilin Province, Hadaling Mountains, flowing through five counties and cities of Panshi City, Yitong County, Changchun City, Dehui City and Nong'an County, joining the Yinma River in the east of Kaoshantun of Nong'an County and finally flowing into the Songhua River.

In the past ten years, the action for improving ecological environment management of the river section in Yitong County has been carried out, and some gates and dams have been built to enhance the effect of the urban landscapes, including a flap gate located 800m upstream of the Yitong River North Bridge in the urban area of Yitong County, built in 2012. It is one of the main water-retaining buildings in the urban section, mainly playing an ecological landscape role. The flat gate is 110m long, and 2.3m high, consisting of 12 spans, with each being 9.15m wide. The control basin area above the gate site is 588km^2. The area where the flap gate is located has a huge temperature difference between summer and winter in a year, with short spring and autumn, as well as cold winter due to the northwest monsoon and the river basin subject to the impact of the Siberian continental air mass. The average daily temperature is below zero is up to five months, from early November to late March. The extreme minimum temperature reaches -40.6°C, the number of stable freezing days is 141 days per year, and the ice thickness reaches as great as 0.8m~1.1m.

The flap gate has been in operation for nearly ten years. However, there are no reliable anti-freezing measures, so the flat gate will be lowered to drain water before the coming of the freezing period every time. The flap gate has never been operated with water reserved in winter. As show in Fig.1. Even so, the flat gate still suffers concrete breakage to some degree, leakage of the water stop structure, failure of the hydraulic system and other problems, which have seriously threatened the safe operation of the flat gate, so every year after winter, maintenance of the gate will be very costly.

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Figure 1 Winter operation of the flat gate without any device

2. Hazard of Freezing to the Gate

The rivers, lakes and channels in high latitudes will freeze in winter, and the formed ice layer will cause ice pressure damage to the gates that directly contact it, resulting the gates' tilt, panel deformation, breaking, rusting, aging and other problems, and even resulting in their failure to open and operate, affecting the safety of the river [1]. It is mainly because that the temperature change causes the ice to expand, producing static ice pressure to the gates, and the water level change produces an upward lifting force or downward pull force on the ice, so that the firmly frozen gate cannot bear the load caused by the ice cover, resulting in deformation or damage of the gate, water-stop components, hydraulic systems, etc. [2-5]. Another reason is that the gate is under water or subject to water level changes for a long time, the temperature change causes repeated freezing-thawing damage to the internal pore spaces of the concrete gate, which gradually makes the concrete on the surface of the gate to fall off, affecting the overall strength.

According to Article 3.1.9 of *Design Specification for Steel Gates of Water and Hydropower Projects (SL74-2019)*, 'the gate shall not withstand the static ice pressure'[6], and to ensure the secure operation of the gate in winter, it is necessary to intervene it with external means to form a non-freezing belt before the gates. At present, the anti-icing measures that are widely used at home and abroad mainly include pressure water jet method, pressure air blowing method, heating method, ice cover grooving method, heat preservation method, etc. [7-9]. These methods generally face such problems as high investment, extensive energy consumption, high personnel and maintenance costs, etc.

In order to solve the winter operation problem of the Yitong River flap gate, the new MDD with independent intellectual property rights was selected in this project. The prototype observation and research was carried out, and the application mechanism and application effect was analyzed and discussed.

3. Principle and Structural Performance Characteristics of the New MDD

3.1 Operation Principles of the New MDD

The new MDD combines the principles of pressure water jet method and pressure air blowing method. It uses high-performance air entrainment technology to form micro-nano gas-mixed water flow, to promote the bottom water body and the surface water body to flow forward rapidly in a fan shape, and exchange energy with the bottom water body, to fully disturb the water body, and reduce the existence of ice nucleus in the water body, thereby not only making the ice on the frozen layer thaw, but also preventing the water surface from freezing.

3.2 Structural Performance Characteristics

The new MDD is mainly composed of high-performance motor, integral stainless steel

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submersible anti-erosion protective cover, jet pipe, drainage tube, bleed air tube, water-inlet grille and other components. See Fig.2 for details.

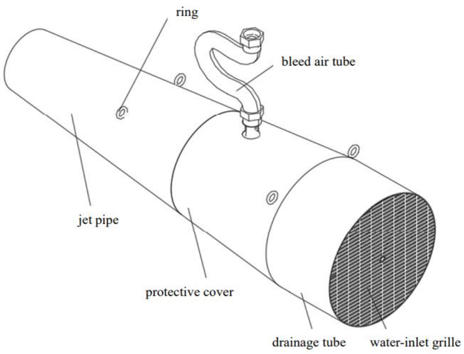

Figure 2 Composition of MDD

The main performance characteristics of the new MDD are as follows:

(1) All parts are made of stainless steel, which can effectively prevent erosion and rust;

(2) The air entrainment technology of the high-performance motor can mix air with water to form micro-nano air bubbles, so that the ice layer is disturbed under the bubbles and the pushing water body, thereby improving the anti-icing and ice thawing efficiency;

(3) With lateral pushing and wide control range, a fan-shaped plug-flow aeration zone with a radius of about 15~25m and an angle of about 30°~60° can be formed in the front side of a single device, as shown in Fig.3;

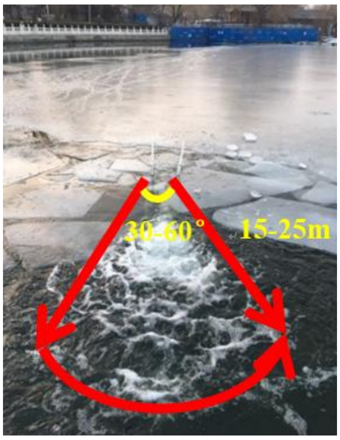

Figure 3 Control range of MDD

(4) The energy consumption of MDD is small, the operating power consumption per linear meter per hour is 0.11~0.15kwh, greatly reducing the operating cost;

(5) MDD is compact and easy to install, maintain and overhaul;

(6) With a wide range of application, MDD is applicable especially for the projects with winter operation demands in reservoir dams, embankments, hydraulic structures, gates and villa area water landscapes. Besides, it is also applicable to both projects under operation and under construction.

4. Application

4.1 Layout of the New MDD

A total of four MDDs were arranged upstream of the flap gate perpendicular to the direction of water flow, and the water outlet of MDD was installed 0.3m underwater. The motor power of each MDD was 2.2KW, the air suction volume was 46m^3/h, and the circulating water volume was 615 m^3/h.

4.2 Monitoring Instruments

In order to test the operation effect of the new MDD, relevant measurement was conducted at

ISSN:2790-1688 DOI: 10.56028/aetr.3.1.762

site, and the measured parameters mainly included water temperature and aeration concentration in water, etc., to quantitatively analyze the performance of MDD.

The monitoring instruments mainly include water temperature measuring instrument and aeration concentration meter, and their performance indicators are as follows:

(1)Fluke1529, the thermal resistance thermometer produced by Hart Scientific; Pt100, the temperature sensor - industrial platinum thermal resistance, with an accuracy of 0.002 ~0.03℃

(2)Second-class standard mercury thermometer, with a measuring range of -30~20 °C, allowable error of ± 0.2°C, and correction value at 0°C of -0.06°C;

(3)CQ6-2005, aeration concentration meter developed by China Institute of Water Resources and Hydropower Research, is a resistive aeration concentration meter, and its sensor adopts plate electrode, which measures the percentage of the volume of gas passing through the water body between the plates and the volume of water-vapor mixed water body. In this test, two aeration concentration sensors were used, and the spacing between the aeration sheets was 10mm (Sensor 2#) and 20mm (Sensor 1#) respectively.

4.3 Test Results

4.3.1. Water Temperature. During the test, the outdoor temperature was -6.73~-7.13°C, and the water temperature at 0.5m underwater measured by the thermal resistance thermometer was 1.0°C. In order to analyze the authenticity of the underwater temperature test, the test results from the second-class standard mercury thermometer and the thermal resistance thermometer at different temperatures were compared, and the results are detailed in Table 1.

Table 1 Comparison of Temperature Measurement Results of Two Types of Temperature Measuring Device (Unit: °C)

Item	Test Group 1	Test Group 2	Test Group 3	Test Group 4
Thermal resistance thermometer	0.19	1.10	0.66	3.72
Second class standard mercury thermometer	0.30	1.10	0.55	3.70
Difference	-0.11	0.00	0.11	0.02

Through comparison, it can be seen that the measurement results of the two instruments have positive and negative errors, and the maximum error does not exceed 0.11 °C, which is within the allowable error range, so the measurement results of the platinum thermal resistance are considered to be true.

4.3.2. Aeration concentration in water. Three test lines were arranged along the direction of the device axis, namely, perpendicular to the direction of water flow, of which one test line was located in the center of the device axis, and the other two test lines were arranged 1.0m before and after the center of the device axis respectively, and three test points were arranged on each test line, and the spacing between test points was 1.0m The test point locations are shown in Fig. 4.

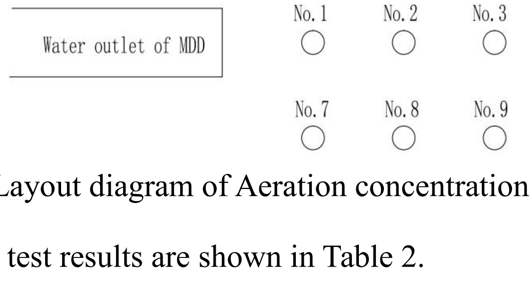

Figure 4. Layout diagram of Aeration concentration test point

The aeration concentration test results are shown in Table 2.

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Table 2 Results of Aeration Concentration Test (%)

Test Points	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8	No.9
Sensor 1# (20mm spacing between the aeration sheets).	1.87	1.32	0.12	0.08	0.10	0.12	0.00	0.00	0.00
Sensor 2# (10mm spacing between the aeration sheets).	2.57	2.16	0.18	0.10	0.20	0.20	0.02	0.06	0.00

As seen from Table 2, the measurement results of each test point of Sensor 2# are greater than those of Sensor 1#, and the reason is mainly that the bubbles were not uniformly distributed in the water body. As the spacing between the aeration sheets decreases, the relative volume of bubbles of the same particle size in the small-pitched aeration sheets increased, and the aeration concentration also increased. From the test results of Sensor 2# alone, the water aeration concentration at the test point on the center of the device axis was relatively high, and the maximum aeration concentration of No.1 test point was 2.57%; while the aeration concentration on the front and rear test lines was relatively low, and the aeration concentration in the water body was close to 3m away from the outlet of the device, which indicates that the aeration concentration decreased with the increase of the spacing.

4.4 Operation Effect of the new MDD

Before the new MDD was installed, the thickness of the ice layer before the flat gate was about 7cm, and the ambient temperature was -7 °C. Following 7 days of trial operation of the new MDD after installation, there was no ice cover within about 5m before the flat gate, and there was ice formation near the pier behind the gate, but it didn't affect the secure operation of the flap gate. The actual operation period of the new MDD was from November to March of the following year, and the new MDD operated 24 hours a day, experiencing extreme low temperature of -27 ° C in the Yitong River area. There was no ice cover, flowing ice sheet, or ice flowers within 10-15m before the flap gate, and the control range of a single device was 27.5m. By contrast, the maximum ice thickness in the upper reaches was already 80 cm. Obviously, the new MDD not only has an ice-thawing effect, but also has a good anti-icing effect, enabling the secure operation of the flap gate in winter, and also improving the winter landscape of the river, making it available for the icing area of upstream serving as an ice entertainment place for citizens. As show in Fig.5.

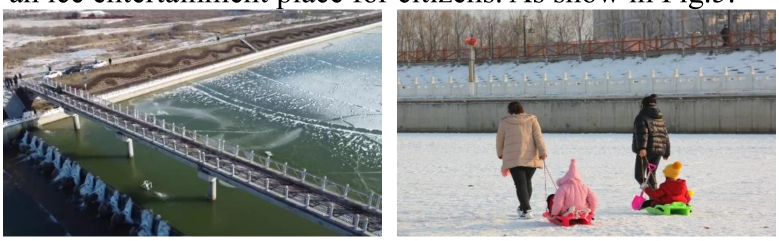

Figure 5. Operation effect of the new MDD

5. Conclusion

Through the application of the new MDD in the Yitong River flap gate, the hydraulic parameters such as water temperature and the aeration concentration in the water body were measured, and the anti-icing and ice-thawing effects of the new MDD were observed. Through the data analysis, it can be summarized as follows:

(1) The new MDD has the effect of thawing ice. Through the measurement of water temperature, it can be seen that the water temperature at 0.5m underwater is controlled at about 1.0°C, and the new MDD pumps the water with higher temperature in the middle and lower parts of the river, exchanging heat with the upper water with a lower temperature, thereafter, the water comes into

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contact with the ice, so that the ice absorbs heat and gradually thaws.

(2) The new MDD has anti-icing effect. By pumping air, the dissolved oxygen concentration in the water body and the air content in the water body are increased, and the closer to the water outlet, the higher the air content of the water body will be. The resulting micro-nano gas-water mixture can effectively reduce the formation rate of ice nucleus in water and reduce the formation of ice flowers on the surface of water bodies.

(3) The new MDD operates stably and has a wide control range. Through the horizontal jet of the new MDD, the bottom water body and the surface water body are promoted to spread forward rapidly, so that the water body is strongly turbulent, and through a winter's operation, there is no freezing phenomenon in the whole river section within 15m upstream of the flap gate. For a 110m-wide river channel, the control range of each device reaches 27.5 m.

In conclusion, the new MDD achieves low energy consumption, low cost, easy installation and easy maintenance for freezing prevention, which can effectively solve the damage to the gate caused by freezing of water in the cold area of northeast China, prolong the service life of the gate, and ensure the safe operation of the project, boasting broad prospects for promotion and application.

Acknowledgments

This work was financially supported by Five Talent Programs-High level International Compound Talents of China Institute of Water Resources and Hydropower Research (0203952012).

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