Available online at www.sciencedirect.com
ScienceDirect
Journal of Hydrodynamics
Ser.B, 2007,19(3):342-348
sdlj.chinajournal.net.cn

NUMERICAL SIMULATION OF ICE CONTROL EFFECT OF SOLAR ENERGY ON TIBETAN CHANNELS*

AN Rui-dong, CHEN Ming-qian, LI Ran
State Key Laboratory of Hydraulics and Mountain River Engineering， Sichuan University, Chengdu 610065, China, E-mail: ruidongan@hotmail.com
Banjiuciren
Rikaze Water Conservancy Institute of Tibet, Rikaze 857000, China
SHI Yun-qiang
Tibtan Weather Bureau, Lasha 850000, China

(Received September 8, 2006; Revised October 16, 2006)

ABSTRACT: With the Tanghe Diversion Channel in Tibet as an example, the theoretical study on the ice control effect of the solar sacks was conducted based on the previous study. The numerical simulation method was adopted and a one-dimensional numerical model for ice crystal in diversion channels in high-altitude cold regions was developed in this article. The heat transfer through the air-water interface and the mass transfer between ice and water were considered in the model. The model was validated by the field observation data on the diversion channel of the Tanghe Hydropower Station. The results show that the ice control effect of the solar sacks is obvious in the channel with large mass flow rate in the high-altitude cold regions.

KEY WORDS: solar energy, solar sack, ice control, diversion channel, numerical simulation

1. INTRODUCTION

In high-altitude cold regions, such as Tibet in China, most of small and medium hydropower stations are of diversion type, and the lengths of the diversion channels in Tibet range from several kilometers to more than 10 km. Because winter is cold and long in Tibet, the ice problem of diversion channels is serious. Ice damage has been the key problem which restricts the hydropower stations, especially the diversion hydropower stations, to run normally in winter. Due to the specific climate and geographic characteristics, the ice regime has its unique characteristics. For the obvious diurnal variation of ice formation and melting, the stable ice cover can not be formed and the main ice form is the suspended ice crystal, resulting in difficult ice control measures. At present, the traditional ice control measure is to cover the channel with the concrete plate, but its cost is high and it is difficult to clean the silt when the channel is jammed by ice.

Fig. 1 Solar sacks

* Project supported by the National Natural Science Foundation of China (Grant No.50469002).
Biography: AN Rui-dong (1983-), Male, Ph.D. Student
Corresponding author: CHEN Ming-qian, E-mail: chenchen-qian@126.com

As the solar energy is abundant in Tibet, the local researchers explored a kind of solar sacks[1] and carried out the ice control experiment using solar sacks in recent years. The solar sack is made of black macromolecule decalescence material and designed as a series of parallel gasbags. Figure 1 is the photo showing the solar sacks. Figure 2 gives the sketch the cross sectional view of the solar sacks.

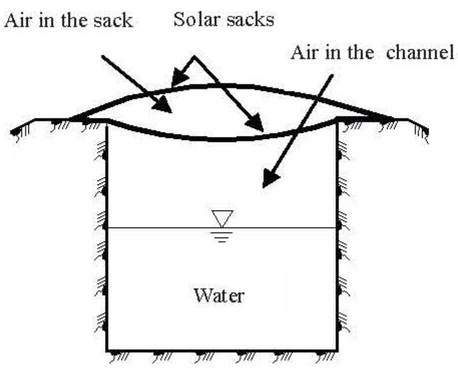

Fig. 2 Sketch of the cross sectional view of the solar sacks

The experiment was conducted on the channel located at the Nanmulin County on the right bank of the Xianghe River of Tibet. The earth channel is 150 m long and 0.7 m wide. The experimental flow rate is 0.075 m^3/s -0.296 m^3/s and the velocity is 0.67 m/s-1.17 m/s. The results show that the ice control effect of the solar sacks on the channel with small flow rate is obvious, but on the channels with large flow rate, it needs to be studied further. There are two kinds of research method for it field experiment and numerical simulation. As the cost for field experiment is especially high and is restricted to be conducted in winter, the numerical simulation is necessary. It can save the cost and time for the research, and provide theoretical references for the field experiment.

There is much research on the numerical simulation of ice problem at home and abroad. But there has been less for the ice problem in the Tibetan high-altitude cold regions. The RICE model is one of the famous model developed by Lal and Shen[2]. In this model, the hydraulic variables were determined by solving the one-dimensional unsteady flow equation, the water temperature was simulated with the energy equation, and the ice crystal was controlled by the transportation and diffusion equations. The impact of float ice and bank ice on ice cover was also considered. Later, Wang et al. [3] studied the parameters in the RICE model. Shen[4] developed the RICEN model, which was a more refined river ice model. The super-cooling phenomenon and anchor ice could be simulated by the RICEN model. Wind, destroying ice artificially and drag force between ice and flow were also considered in the RICEN model. Recently, Sui [5] has conducted the experimental research on ice jam evolution and water level of the Yellow River during ice period. Li [6] studied water transport problem under ice cover in channel. Zeng [7] established numerical turbulence model for ice melting. None of the above models, however, address adequately the modeling of ice control, which may be essential for some diversion channels.

Through considering the mass transfer between ice and water and the heat transfer through the air-water interface, a one-dimensional model of ice crystal formation and melting in diversion channel is established in this article[8,9]. The ice control effect of solar sacks is simulated and studied. It will provide theoretical reference for modeling ice control measures of diversion hydropower stations in the Tibetan high-altitude cold regions. The diversion channel of the Tanghe Hydropower Station in Tibet is taken as an example, which is 14.254 km long and 2.5 m-7.0 m wide. Its flow rate is large, with the maximum of 8 m^3/s, and the maximum velocity is 0.63 m/s-3.87 m/s. Banjiuciren et al. conducted field observation on the ice regime of the Tanghe Channel from December 2005, to January 2006. The numerical model developed in this article is validated by the observation data.

2. NUMERICAL MODELS

2.1 *Governing equations*

The model consists of the kinematic equation of flow, volume fraction equation of two-phase flow, and heat convection and conduction equation of water phase.

2.1.1 Kinematic equation of flow

The Saint-Venant equations of flow without tributary are as follows:

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=0 \tag{1}$$

$$\frac{\partial Q}{\partial t}+\frac{2Q}{A}\frac{\partial Q}{\partial x}+\left[gA-B\left(\frac{Q}{A}\right)^2\right]\frac{\partial z}{\partial x}=$$