Journal of Research in Multidisciplinary Methods and Applications (JRMMA)
ISSN: 2957-3920, Volume 1, Issue 1, May 2022

High Lift, Long Distance and Long Pipe Diameter Water Pressure Penstock Structural Design and Calculation

Liu Zhongxian*, Yang Shenggang, Hu Bo, Wu Yongbo

Guizhou Water Resources and Hydropower Survey, Design and Research Institute Co., Ltd, China, 550000

**Corresponding to: Liu Zhongxian, 1051941667@qq.com*

Abstract*: high lift, long distance, large diameter water engineering is about the research of water conservancy, based on the actual engineering experience, it is proposed that, in the analysis of water pressure pipe structure design and the pressure steel pipe structure calculation, the calculation condition should be divided into normal operating conditions and emptying condition, in hydraulic pressure experiment, hydraulic pressure selection should be 1.25 times the results of excessive water hammer pressure.*

Keywords: high lift; long distance; large pipe diameter; pressure steel pipe; structural design

1 Introduction

Water distribution is very uneven in China, water engineering is very important for balance of water resources and promote healthy economic and social development, and in water engineering, high lift, long distance pressure pipe water is the design of such engineering, this paper from the Guizhou Weining river secondary water engineering design, the study discusses in high lift, long distance, large diameter water pressure pipe structural design and calculation need important research and attention, the conclusion can be used in similar engineering.

2 Project introduction

In Weining county, Guizhou Luoze river water project main task for Weining emergency water supply and irrigation water supply, mainly in the dry season to Weining county south Luoze river water to the county important drinking water source Yang bay bridge reservoir, to make up for the problem of insufficient water supply, project scale for medium-sized, engineering for III, etc., total water flow of 1.2 m^3/s. Q345R pressure steel pipe with two-stage water extraction scheme, a diameter of 1m, the length of 5.84 km and the water flow of 1.2 m^3At / s, the lifting lift is 244 m, the diameter of the secondary lifting pipe is 0.9 m, the length of the lifting pipe is 7.65 km, and the lifting flow is 1.0 m^3At / s, the water lift is 172 m. In the case of single parameter index, the water flow and pipe diameter and length are not the largest in Guizhou Province, but considering the water flow, pipe diameter and lift, it is the largest high lift, long distance and large pipe diameter water lifting project with the comprehensive relevant parameters in Guizhou Province.

3 Internal water pressure calculation

The most important part in the structural design of water lifting engineering is the calculation of internal water pressure. The calculation of internal water pressure is relatively complex. At present, there are many software to calculate internal water pressure on the market. According to engineering experience and theoretical research, bentley-hammer software is used for this design. According to the specification and engineering experience, the pipeline should not only calculate the water hammer under the extreme working conditions of the no-water hammer discharge measures, but also consider the different working conditions according to the appropriate water hammer protection measures (air valve, water shock prevention valve / discharge valve), and the modeling calculation assumes four working conditions in the calculation:

Working condition 1: the air valve, the water strike prevention valve / discharge valve operate at the same time, and the setting value of the water strike discharge valve is 1P.11 working pressure;

Working condition 2: air valve, water strike prevention valve / relief valve action at the same time, the setting value of water strike relief valve is 1P.30 working pressure;

Working condition 3: the air valve, the water strike prevention valve / discharge valve operate at the same time, and the setting value of the water strike discharge valve is 1P.44 working pressure;

Working condition 4: Scheme 4: air valve action, water strike prevention valve / discharge valve failure

Over calculation results under different working conditions are as follows:

Table 1 Calculation statistics of secondary lift pipe transition process under different combined working conditions

#	Prevention and relief valve setting value	After working valve			Town pier 50 (lowest point of pipeline layout)			Minimum unit speed / rpm
		rated pressure /m	maximum pressure /m	Highest / rated	rated pressure /m	maximum pressure /m	Highest / rated	
Plan	P1=70m(0.52P)	172	196	1.09	263	298	1.13	+36

1	P2=190m(1.10P) P3=195m(1.13P)							
Plan 2	P1=70m(0.52P) P2=225m(1.31P) P3=230m(1.34P)	172	229	1.33	263	323	1.23	+36
Plan 3	P1=70m(0.52P) P2=250m(1.45P) P3=255m(1.48P)	172	254	1.48	263	341	1.30	+36
Plan 4	Water shock prevention / discharge valve failure	172	324	1.88	263	381	1.45	-91

According to the above calculation results, the air valve, water shock prevention valve / discharge valve (scheme one, 2,3), the maximum reverse speed and pressure appreciation meet the requirements of the specification, the air valve action, water shock prevention valve / discharge valve failure (scheme 4) the maximum counter speed meets the specification requirements, the pressure appreciation is 2.2 times, above the requirements of the Code for Water Conservancy and Hydropower Steel Pipe (SL / T281-2020, hereinafter referred to as the specification).

According to the "specification", for high lift, long distance, large diameter water transmission pipe, in the pipe structure calculation, when water discharge valve, air valve failure, it should be the water pressure in the pipeline is more than 1.5 times, after consulting a lot of data and reference to Guizhou rock water conservancy project, Qian water conservancy engineering experience.

4 Preliminary drawing of pipe wall thickness

In the design of pipe wall thickness, the initial wall thickness should be calculated according to the water pressure results in the third pipe, and then the initial wall thickness combined with the upper load of the pipe for the pipe structure.

According to the Code, the wall thickness of pressure steel pipe shall be calculated.

The calculation thickness of the pipe wall corresponding to the maximum internal water pressure of the pipe is 12mm. It is worth noting that the Specification clearly states that due to long-term exposure, water gas, soil and other physical and chemical factors have some corrosion on the pipeline, so the pipe should be increased by at least 2mm over the wall thickness to ensure that the pipe will not be damaged under corrosion caused by other physical and chemical factors, so the maximum wall thickness is 14 mm. The rest can be calculated according to the water machine according to different internal water pressure.

5 Pipeline structure calculation

5.1 Calculation working condition and load combination

Pipeline structure calculation is the core of the whole pipeline design. In the calculation, load combinations under different working conditions should be selected according to the requirements of the Code, and then structure calculation should be conducted according to each load combination.

The basic load combination included in the calculation conditions of pipeline structure analysis is: the highest internal water pressure, structure and water weight, temperature stress, soil pressure, and construction load under normal operating water level. When calculation, different operating conditions should be divided, and then the corresponding load should be found under the corresponding working conditions for calculation.

Analyzing the different operating conditions of the secondary lifting pipe, there are three working conditions in the actual operation: normal operation condition, emptying condition and special load combination condition, and the special load combination can be divided into construction condition, water filling condition, hydraulic pressure test condition and the highest-pressure condition of the highest operating water level.

For the incoming water flow of the lifting pipeline, the lift is certain, and the highest pressure condition under the highest water level is the normal operation condition of the pipeline under the rated power condition of the pump, which cannot be considered, mainly comparing the hydraulic pressure test condition, water filling condition and construction condition.

Under the construction condition, the pipeline is equivalent to the working pressure of the pipeline, according to the hydraulic test pressure is the same value of the maximum internal water pressure under the highest water level. This pressure is equal to 1.25 times the maximum water hammer pressure.

In conclusion, three working conditions should be considered in the calculation of pipeline structure, namely, normal operation condition, emptying condition and hydraulic test condition, in which the hydraulic test condition is the control condition.

5.2 Stress calculation

According to the Specification, the stress of the calculated points shall meet the following conditions:

(1) The calculation according to the plane structure

(2) The calculation according to the spatial structure

In fact, if calculated according to spatial structure, pipeline stress is very complex, in the current market environment also lack of corresponding calculation software, such as pipeline not through highway, railway and in strong seismic zone upper load, complex areas, can be considered as plane structure, only under different conditions of load calculation method in the appendix of the code one by one, then synthetic pipeline axial, ring, radial positive stress and shear stress, then according to the plane structure formula.

After calculation, the maximum stress and corresponding wall thickness of the secondary lifting pipe are shown below

Table 2 Calculation condition and load combination of backfill pipe structure analysis

#	project	computational formula	unit	Wall thickness t0 (mm) (calculated thickness of pipe wall)			remarks
				DN800			
				14	12	10	

1	permissible stress φ[σ]	Normal operating conditions	Basic combination	N/mm²	180.26	180.26	180.26	
		Hydraulic test condition	specific combination		262.2	262.2	262.2	
		Empty working condition	Basic combination		180.26	180.26	180.26	
2	Whether the allowable stress is satisfied	Normal operating conditions	Basic combination		satisfied	satisfied	satisfied	heat drop
		Hydraulic test condition	specific combination		satisfied	satisfied	satisfied	
		Empty working condition	Basic combination		satisfied	satisfied	satisfied	
		Normal operating conditions	Basic combination		satisfied	satisfied	satisfied	temperature rise
		Hydraulic test condition	specific combination		satisfied	satisfied	satisfied	
		Empty working	Basic combination		satisfied	satisfied	satisfied	

6 Conclusion

High lift, long distance, long pipe diameter water lifting engineering has been the focus of research in water conservancy engineering discipline, Based on the structural design of the secondary water lift pipeline of Luoze River Water Lift Project in Weining County, Guizhou Province, The internal water pressure, pipe wall and structure of the water pressure steel pipe are analyzed, In the calculation of the internal water pressure, The pipeline shall be overcalculated considering the discharge measures, According to the most unfavorable working conditions of the overcalculation results to participate in the subsequent pipe wall and structure calculation, In the calculation of the penstock structure, The calculated working conditions shall be classified into normal operating conditions, charge condition and hydraulic test condition, The control condition is the hydraulic test condition, The internal water pressure in the hydraulic test condition should be 1.25 times of the water hammer pressure of the water machine.

Reference

[1]《Code for Design of Pressure Steel Pipe for Water Conservancy and Hydropower Engineering》(SL / T281-2020 , China Water Conservancy Industry Standard)
[2]《Code for Design of Outdoor Water Supply System》(GB50013-2018 , China Water Conservancy Industry Standard)
[3]《Code for Design of Pipe Structure of Water Supply and Drainage Engineering》(GB50332-2002 , China Water Conservancy Industry Standard)
[4]《Code for Construction and Acceptance of Water Supply and Drainage Pipeline Engineering》(GB50268-2008 , China Water Conservancy Industry Standard)