Design of Hollow Cone Water Gate with Hydraulic System in Karangkates Dam

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Abstract

Water gate system in a dam is to control the water flow. It also controls the water surface elevation being stored or routed. The hollow cone type was designed as it has the most efficient energy of dissipation. It also has a simple construction, the relative affordable cost, and it can be operated electromagnetically or in hydraulic system. The hollow cone design gives a stable debit coefficient and can be implemented in big scale. Method used in this design is the data collection and calculation of dimension scale and water gate capacity. Result of the calculation determined the capability of hollow cone water gate to control the maximum debit of 5,9251 m³/s, the operation load of 2.875,92 kg, tensile stress around the valve 2,0108 kg/mm². The design of hollow cone system used the SC30C of M20 nut.

Keywords: *dam; design; Hollow Cone water gate; Hydraulic*

1. INTRODUCTION

The Karangkates Dam is located in Brantas River, Malang, Indonesia. This dam has maximum reservoir capacity of 1,050-kilometer square [1], the volume capacity (net volume) is 343 million cubic meters, the effective water capacity is 253 million cubic meters, and the sediment capacity is 90 million cubic meters [2,3].

The Karangkates Dam is built to be a reservoir for society in Malang and Blitar regency, especially those who live in the surrounding of Karangkates Dam. It is expected to supply the water for the irrigation of 34,000-hectare rice field. It is also needed for reservoir in 24,000 liter/second debit of capacity to develop fishery field, controlling, or avoiding the flood during the wet season. The water flow from the dam is also utilized for electrical with 105 MW of power [4]. The dam is also the magnetism for tourism. Therefore, the Karangkates Dam becomes the tourism destination for the domestic and abroad tourists. The function extended to the conservation area of Brantas Watershed [5].

As the gate for controlling water flow and reservoir, the Karangkates Dam had been built with parts and function. They are body of dams, foundation, gates, spill way, canal, reservoir, and valves. The valve functioned to control the water flow in rotation or transverse movement in the water ways. This function is almost the same with other water gate, but its advantage is the capability to restrain higher water pressure (water pipe or fast pipe). The considering factors in planning and choosing the valve is the pressure capacity, the factor of fluid loss, the valve components, the material of valve, and the type of valve [6].

From the considerations in planning the valve for Karangkates Dam, the hollow cone type is regarded as suitable. The points of selecting the hollow cone type of the valve are the energy dissipation efficiency, the simple construction, and the building is in low cost. Moreover, it can be operated with electromagnetic and hydraulic pump. It has good debit coefficient and can be implemented to bigger size.

2. METHODS

The design of the hollow cone valve for the Karangkates Dam needed numerical data for drafting. Prior to designing the hollow cone valve, the procedures to determine the specifications were conducted. It was initiated with the calculation of maximum debit, operation load, operation mechanism, dan design.

The calculation of maximum debit was obtained from the debit of penstock pipe. The width of the valve aperture is not allowed more than 90% of the penstock pipe surface width. It is aimed to adjust the debit and the water gush from the valve as required to the specifications of Karangkates Dam.

Similarly, the calculation of operation load was conducted to find out the total load on the valve during operation. The load included the load under the hydrostatic pressure, the friction, and the density load. In this calculation, the hydrostatic pressure was calculated to find out the pressure force of valve. Hydrostatic pressure is the water pressure influenced by gravity and the high-water gush. The higher of water pressure, the higher hydrostatic pressure. Moreover, the friction on the valve is caused by the friction of sliding gate valve and the bearing of sliding gate valve.

Furthermore, the operation mechanism is obtained from the determination of hydraulic pump specification. Before it comes to the specification, the calculation was conducted in the pressure value, force, and the volume of hydraulic tube. The hydraulic tube is needed to drive the hydraulic piston in open and close operation.

The data obtained from the calculation showed the specifications of the hollow cone valve for Karangkates Dam. The valve was designed to Dam with the height of water pressure 38.85 m with the diameter of 700 mm. It is designed to operate with hydraulic system.

3. RESULT AND DISCUSSION

The force of water jet is caused by the water gush hits the convex wall. It resulted the pressure jump. The water jet in the hollow cone valve occurs when the water in the penstock pipe flows and hits the dispersing cone (the dispersing cone functioned to distribute the flow). It resulted the force of water jet when the valve is open.
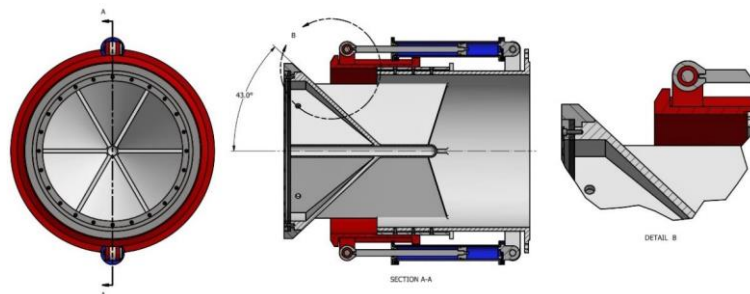
Gambar 1. Open hollow cone valve

In designing the hollow cone valve for Karangkates Dam, the material was determined to steel. It has the value of friction coefficient of 0,74. In finding out the mass of the Sliding Gate Valve the features in Inventor Properties in Autodesk Inventor software are used.
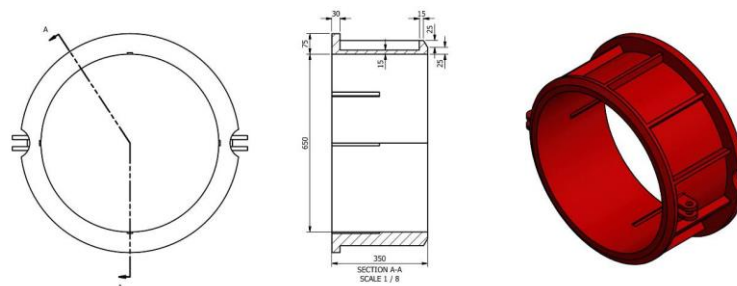
Gambar 2. Sliding Gate Valve

When the flowing water in a pipe is immediately constrained by closing the valve, the dynamic energy will be changed to elastic energy. Therefore, the positive and negative waves will have reciprocating movement in the pipe. Moreover, it will be stopped by the friction. This phenomenon is also known as water hammer.

The width of penstock pipe surface (Apenstock) is calculated to find out the appropriate opening valve. The wide of opening valve cannot be more than 90% of the Apenstock surface width. It is aimed to obtain the appropriate criteria of debit and water jet for Karangkates Dam. The surface width of Apenstock can be calculated with Avalve equation.

$$Avalve = Apenstock \; x \; 90\% = 0{,}34632 \; m2$$

When the valve opening area is found out, the valve opening width is needed to be calculated. The width of the valve opening is the width of the sliding gate valve opening from a closed condition. To find the width of the valve opening can use the equation.

$$Aopen = \pi.d.t$$

Avalve has the same value with Aopen, d is the diameter in *Valve Body* (mm), t is the wide of *Sliding Gate Valve* (mm) A_{open} = π. (0,7 m). t 0,34632 m2 = 2,199 t

$$t = \frac{0{,}34632}{2{,}199} = 0{,}157 \; m = 157 \; mm$$

therefore, to find the maximum debit of the valve, it can be calculated by Q equation.

$$Q = cd.A\sqrt{2gh}$$
$$Q = 0{,}62 \; x \; 0{,}34632 \; m2 \sqrt{2 \; x \; 9{,}8 m/s^2 \; x \; 38{,}85 \; m} = 5{,}9251 \; m3/s$$

The operational load is the loads proceed in the hollow cone valve. In the design of hollow cone valve, the operational load is calculated to find out the capability of valve to restrain any types of loads run or operate in the valve.

The hydrostatic pressure in hollow cone valve can be calculated with p equation [7]:

$$p = \rho.g.h$$

p is the hydrostatic pressure (N/m^2), ρ is water density (1.000 kg/m^3), g is gravity (m/s^2), and h is the height of water pressure (m), p = 1.000 kg/m3 x 9,8 m/s^2 x 38,85 m = 380.730 N/m^2 = 38.832,6554 kg/m2 = 38,8 ton/m^2

The pressure force (F_s) in *Sliding Gate Valve* can be calculated with Fs equation [7]:

$$Fs = p \; x \; As$$

As is the different width of *Sliding Gate Valve* and *Valve Body* (m^2). It can be calculated with As equation.

$$As = \frac{\pi}{4} \; x \; (d_s - d_b)2$$

ds is the diameter of *Sliding Gate Valve* (m), while db is diameter of *Valve Body* (m), As = π/4 x (0,75 m − 0,7 m)2 = π/4 x (0,05)2 = π/4 x 0,025 = 0,0019625 m^2. In calculating the pressure force in the Sliding Gate Valve (Fs), it can be calculated with Fs equation.

$$Fs = p \; x \; As$$

p presents the hydrostatic pressure (kg/m^2), that Fs = 38.832,6554 kg/m^2 x 0,0019625 m^2 = 76,209 kg.

The shear stress value of the bolt (τ_b) and the shear stress of the nut (τ_m) are lower than the allowed shear stress ($\tau\alpha$ = 4kg/mm^2). Therefore, the M20 nut and bolt is allowed to be the joint fastener of valve body with the penstock pipe*.*
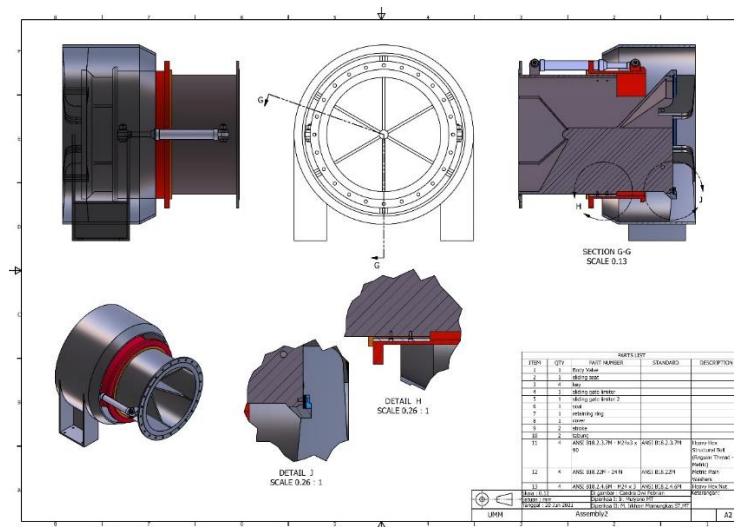
Gambar 3. Design of hollow cone valve for the dam

4. CONCLUSION

Based on the result of calculation for designing the hollow cone valve applied in Karangkates Dam the debit maximum for the valve is 5,9251 m^3/s. The operation load obtained the value of 2.875,92 kg, while the tensile stress of the valve is 2,0108 kg/mm^2. The material used in the design of the cone fin is S30C with maximum stress of 0,02923 kg/mm^2.

The specifications of hydraulic power unit are 9 Mpa of pressure, 0.75 kW of motor power, 20 L/min of flow rate, and 10 L of reservoir capacity. The nut and bolt specifications to hold the stress in the valve body joint toward the penstock pipa are S30C of material, the tensile stress of 7,9967 kg/mm^2, the shear stress of the bolt thread root is 2,2351 kg/mm^2, and the shear stress of the nut is 2,5033 kg/mm^2.

REFERENCES

1. Tarigan E. Energy Output Simulation of the Floating PV System of Karangkates Hydropower Dam in East Java, Indonesia. In: 2021 International Seminar on Intelligent Technology and Its Applications (ISITIA). IEEE; 2021. p. 191–6.
2. Akalily A, Harisuseno D. ARTIFICIAL RAIN TECHNOLOGY AS AN ALTERNATIVE INCREASING SUTAMI RESERVOIR VOLUME IN EFFORT TACKLING DROUGHT DUE TO GLOBAL CLIMATE CHANGE. 2012
3. Legono D, Hidayat F, Sisinggih D, Wahyuni S, Suharyanto A. Performance of Flushing Efficiency of Sediment Evacuation from Wlingi and Lodoyo Reservoirs. IOP Conference Series: Earth and Environmental Science [Internet]. 2021 Dec 1;930(1):012078.
4. Abel YP, Rispiningtati, Soetopo W. OPTIMASI POLA OPERASI WADUK SUTAMI MENGGUNAKAN MODEL PEMROGRAMAN LINIER KABUR (FUZZY LINEAR PROGRAMMING). Jurnal Teknik Pengairan. 2015;6(1):95–107.
5. Kasiro I, Isdiana DP, Nugroho CL, Muchtar A, Hari Martadi RS. Bendungan Besar di Indonesia. Pusat Penelitian dan Pengembangan Pengairan, Dept PU, Dirjen Pengairan. 1995;
6. Andrijanto, Sudiana R. Data Operasi Waduk dan PLTA Harian. 2012. p. 1.
7. Maryono A, Muth W, Eisenhauer N. Hidrolika terapan. Yogyakarta Pradnya Paramita. 2001