

Review of Hydraulic Balance and Energy Saving of Cooling Water System

Xuan Ge*

University of Shanghai for Science and Technology, Shanghai 200093, China

*Corresponding Author

Abstract

Cooling water system is widely used in industry, transportation and other fields. Reasonable design and optimization of cooling water system is of great significance to reduce energy consumption and realize energy saving and emission reduction. This paper sorted out the articles about the cold water system in recent years, especially the hydraulic balance of pipe network, pointing out that the influence of the hydraulic balance of pipe network on the whole system can not be underestimated. At the same time, the research of cooling water system from the aspects of cooling water system design, hydraulic calculation and balance debugging device.

Keywords

Cooling Water System; Hydraulic Balance; Balance Valve.

1. Introduction

Since China's reform and opening up in 1978, the domestic economy has achieved remarkable development, and the overall strength has been greatly improved[1]. GDP increased from 367.87 billion yuan in 1978 to 9908651 billion yuan in 2019, an increase of about 269 times in the past 30 years[2]. With the acceleration of China's industrialization process and the large population base, China's energy consumption is second only to the United States, ranking second in the world[3]. At present, energy consumption and environmental problems in social development have attracted more and more attention from countries around the world. Energy conservation and emission reduction has become a hot topic discussed by all sectors of society. In September 2020, China clearly proposed the "carbon peak" of carbon dioxide emissions by 2030 and the goal of "carbon neutral" by 2060. On September 11, 2021, the National Development and Reform Commission issued the Plan for Improving Energy Consumption Strength and Total Control; on October 24, the same year, the CPC Central Committee and the State Council issued the Opinions on Complete and Accurate Implementation of the New Development Concept and Improving the Carbon Peak and other relevant documents, to promote the efficient and steady progress of national energy conservation and emission reduction work[4].

According to the data of the National Bureau of Statistics, the growth rate of China's total energy consumption in the past decade has slowed down somewhat, but it is still growing continuously[6].

According to the People's Daily, industry, construction and transportation in China's energy consumption accounts for about 60 percent of the country's energy consumption[7]. In the petrochemical industry, paper, textile and thermal power generation and other industries, the cooling water system energy consumption is very high, accounting for about 15% of the total social energy consumption[8]. In the process of industrial production, inevitably, a large amount of waste heat, affect the normal operation of the system, and even cause equipment damage. Therefore, the industrial system will generally be equipped with a cooling water

system with auxiliary cooling, which is mainly for the purpose of cooling, used to reduce the temperature of the production device in the process of operation, to ensure the stable operation of the equipment in the appropriate temperature conditions[9]. When the cooling water system is not designed, it will cause huge water waste and excess energy consumption. Therefore, in the design stage to ensure the scientific and rational system design, and choose the best system design and operation scheme can greatly improve the energy utilization rate and reduce unnecessary energy waste.

The research on the energy-saving operation of the circulating cooling water system has begun as early as the last century[10]. However, more research focus on the optimization and transformation of the cooling tower in the cooling water system and the optimization analysis of the power of water pump and fan in the system, often ignoring the influence of hydraulic balance in the pipe network system. When the hydraulic imbalance in the pipe network system, that is, the hydraulic imbalance, will cause the proximal branch flow is too large and the water flow on the most unfavorable loop can not reach the design value. If we blindly rely on increasing the total flow rate of the system to meet the water consumption on the most unfavorable loop, it will lead to excess flow of other branches, resulting in unnecessary energy waste. Hydraulic imbalance is one of the main reasons of energy consumption waste in water system[13]In order to achieve system energy saving, we should first achieve hydraulic balance.

2. Study on the Design and Optimization of Cooling Water System

Whether the large equipment used for processing and manufacturing in the actual production, or the precision instruments used for experimental research in the laboratory, we need to design and install a cooling device (system) to cool the production device to ensure its normal operation.

Cooling water system, mainly composed of cooling equipment, water pumps and pipes. With water as the cooling medium, cold water flows through the production equipment (such as reactor, heat exchange equipment, etc.) to exchange heat, take the heat away generated during the operation of the equipment, and maintain the temperature stability of the equipment. The cooling water system is divided into dc cooling water and circulating cooling water system. In the DC cooling water system, the cooling water is discharged after a heat exchanger for heat exchange, so it is also called a water utilization time. Its water consumption is large, generally not advocated; and in the circulating water system, the cooling water can be reused, the cooling water, the water temperature rise, the heating water into the cooling tower or other cooling equipment, then the water pump to the user, so circulating, can greatly reduce the waste of water resources.

As early as the 1960s, American scholars published articles on the design and economy of cooling systems[15], The paper discusses the influence of different cooling methods and the concentration of the cooling system on the cooling cost, and introduces the materials available with the cooling water system and their limitations. In the design of the cooling system, Ko I W, Choi W J et al[16]In 1996, the probabilistic safety assessment method was proposed, based on the estimated cost, system reliability and hypothesis and probability safety criteria. With the development of computer technology and people's increasing requirements for the performance of transient and steady-state systems, foreign scholars begin to combine computer technology with other disciplines and use computer simulation to evaluate the performance of the closed-loop system[17]. Domestic research on cooling water system started later than abroad. Most of the first articles on cooling water system discuss the design of cooling water system in air conditioning system[18]. After decades of development and the research of many scholars, the design of cooling water system is relatively mature and applied in industrial production, air conditioning system, ship, automobile and many other fields. At the same time,

while the cooling water system meets its cooling effect, people also put forward new requirements for the system energy consumption, water consumption and other aspects. He kai[23]This paper analyzes the whole cooling circulating water system, and proposes that the energy saving optimization of circulating cooling water system should start from the main equipment such as circulating water pump, cooling water pump, cooling tower and cooling tower. Liu Feng proposed an energy-saving technology for designing wet cooling device based on Fluentudf method[24]. Collect and read a large number of research on the energy saving optimization of cooling water system and find that more research focuses on the technical transformation and operation optimization of major equipment such as cooling tower and water pump in the cooling water system[21].

3. Application and Development of Graph Theory in Hydraulic Calculation

The importance and complexity of hydraulic balance are often underestimated, which often prevents the system from meeting its design requirements or causes unnecessary energy waste. In order to make the whole system obtain the required flow under the design condition and reduce the operation cost, it is necessary to study the hydraulic balance of the pipe network.

At the beginning of the design, the water system needs to calculate the flow rate, pipe diameter and water head loss of each pipe section of the system, and choose the appropriate design scheme. But in the actual project, often due to construction, pipe and other factors caused by the actual operation of the flow and design flow is not consistent. Hydrhydraulic calculation of pipe network is conducted to analyze the change of hydraulic condition, and then the system is adjusted to meet the design requirements. When the scale of the system pipe network is large and complex, the hydraulic calculation and debugging of the pipe network often need to be assisted by computer.

Graph theory is a widely used mathematical method. In 1847, Kirchhoff published the Application of Graph Theory in electric Network, which paper made the research method of graph theory widely concerned.1971 American Scholar chan, S.P. We introduce network graph theory and network topology and discuss the application of topology in electrical networks and systems. In 1994, Chinese scholars Chen Gangjun and Lin Jianhua[28]The modern mathematical tool of graph theory is introduced into the hydraulic calculation of ring pipe network, the graph model of ring pipe network is established, and the corresponding matrix equation is established to make the flow calculation and distribution of ring pipe network more convenient. Lv Xiangyang[30]Combined with the basic principle of graph theory and the calculation and analysis method of system hydraulic conditions, he used computer software to simulate different working conditions of the system, so as to provide reference for the regulation of the ring pipe network system with relatively complex hydraulic conditions.Jun J H[31]He applied the graph theory method to calculate the hydraulic pipe network and guide the actual engineering transformation. The results prove that this method has certain guiding significance for the energy saving transformation of the pipe network system. Chen Qiong ring[32]Apply the graph theory theory, establish the corresponding mathematical model, and the MATLAB software is used to write programs for hydraulic calculation, which greatly reduces the workload of hydraulic calculation of complex pipe network system and my verification. By applying the method of graph theory, the complex pipe network structure can be simply represented by the graph composed of a group of points and interrelated lines, so that the complex pipe network system is more simplified and convenient for calculation. At the same time, with the development of computer technology, more and more researchers combine the idea of graph theory with hydraulic calculation, use MATLAB, c + + to write hydraulic calculation programs, and use iterative method for hydraulic calculation. Compared with the

traditional hydraulic calculation process, the use of computer method is more simplified and convenient[33].

4. Study on Water System Balance based on Balance Valve

The research on hydraulic balance system began earlier. In 1953, Tour and Agenturer proposed a method to change the resistance of water flow in the water pipe, so that each terminal device of the system reached the set flow, so as to realize the hydraulic balance of the system. In 1957, Sweden, Anderson (TA water balance company) produced the world's first balance valve, in 1962, obtained the patent of the first balance valve. However, the study of hydraulic balance in China started relatively late than abroad. In 1985, the Standard Institute of China Building Technology Development Center carried out an investigation and research on the problem of hydraulic imbalance[36]. In 1988, Lang Siwei et al[37]Through the investigation and analysis of the actual data, it is shown that the hydraulic imbalance can cause serious energy waste.1997[38]It is pointed out that the main method to improve the hydraulic stability is to reduce the pressure drop of the network trunk, or to increase the systematic pressure drop of the user. In order to better realize the stability of the water system pipe network and eliminate the excess pressure head in the favorable loop of the system, the throttle plate and stop valve equipment are generally used in the early engineering to adjust the hydraulic balance[39]. However, in order to achieve precise hydraulic balance regulation, only relying on the orifice plate and stop valve, its regulation ability is very limited.

In order to better realize the hydraulic balance of the system, more and more scholars began to study and explore the balance valve, and Yang Weicheng began in 1985[17]In this article, a balance regulating valve produced by Tell Anderson (TA) in Sweden is introduced and proposed that the balance regulating valve on the pipeline of each branch of the heating and freezing water system is very beneficial for the hydraulic balance of the system. In 1990, the balance valve machine intelligent instrument independently developed by the Air Regulation Institute of Chinese Academy of Building Sciences was tested and verified that its main performance has reached the level of similar products in Sweden[39].

Since the 21st century, the research on the -- balance valve of the hydraulic balance debugging device has emerged in endlessly. Chen Fushou[41]This paper introduces the adjustment principle of the balance valve and compares the difference between the balance valve and the ordinary valve. Li Xinrong[42]The characteristics and design and selection method of the balance valve are introduced in detail. Wu Yongjie and Zhang Xiaoyong[43]According to the function characteristics, selection and installation of different hydraulic regulating valves, combined with specific examples with detailed guidance. Zhang Houyu[44]The action principle and application of dynamic flow balance valve and manual balance valve are compared. Liu Zhengman et al[45]The "RLY-portable heat network hydraulic balance tester" is developed, which can be inserted into the measuring head in the pipe under the condition of continuous pipe network, and the instrument can show the water flow and temperature in the pipe. Cheng Zhifen et al[46]The working principle and function of self-propelled flow control valve are studied, and the application effect is introduced. The emergence of self-propelled control valve is a major breakthrough in hydraulic balance. Yu Wenhua et al[47]An electronic balance valve integrating balance, control and measurement is proposed to ensure the balance of hydraulic system.

5. Conclusion

In the research of energy saving optimization of cooling water system, more research and analysis are conducted from the cold source and power end, and there is less research on the hydraulic balance and optimization of cooling water pipe network system.

In the design stage of the cooling water system, we should consider the rationality of the hydraulic balance of the pipe network system and the tunability of the pipe network system, and apply the graph theory and the computer method, so as to avoid unnecessary energy waste.

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