© IJEDR 2018 | Volume 6, Issue 3 | ISSN: 2321-9939

A Review Paper Of Evaporative Condenser Cooling System For Air Conditioner

[1]Dr.M.S.Murthy,[2]Adil Shakil,
[1]Group Director MIST,[2]M.Tech Scholar,
[1]Mechanical,
[1]Malwa Group Of Institution, Indore,India
msmurthy16@gmail.com, [2]adilshakil0121@gmail.com,

Abstract - Reducing energy consumption, saving water resources, recycling cool water are main directions of development. Evaporative condenser using latent heat reduces water resources waste, with energy saving advantages. This paper reviews the research status of evaporative condenser at home and abroad, and introduces the principle, classification research direction. , various influencing factors of evaporative condenser, and puts forward the future.

1. Introduction

Our country is a large water-deficit country. In many areas, the economic backwardness causes the shortage of water resources abounds. How to use the existing water resources is one of the key factors of continuous development; China is also an industrial country, thermal power plant, nuclear power plant, Steel and oil and chemical paper mills discharge all waste water containing a large amount of waste heat directly into the surface, which not only increase the temperature of surface water, but also pollute the atmosphere and water. Therefore, recycling efficiently and economically these wasted water resources will play an enormous role in industrial and economic development of our country. In view of this waste of water resources, the appearance of evaporative condenser can greatly alleviate this situation.

2. Classification of evaporative condensers

Evaporative condenser is one of the key equipment for cool water recycling, which uses latent heat as the main heat to exchange mode, while heat exchange, evaporation and condensation simultaneously. There are two major innovations: first, combining air cool and water cool, breaking through the traditional single air-cooled or water-cooled form, a new type of condenser is proposed, which enriches the types of condensers; the second is to combine heat transfer and mass transmission to improve the condensation effect.

According to the heat exchanger system classification, there are two categories: tube type and plate type. The tube-type evaporative condenser can be divided into: packing type, bubble type and special-shaped tube type.

According to the flow direction of air and cool water, it is divided into countercurrent type evaporative condenser and parallel flow type evaporative condenser. The air inlet of the countercurrent type evaporative condenser is in the lower part of the evaporative condenser, the flow direction of the air is opposite to the cool water, the air flows from downward to upward, the cool water flows from up to down, since the heat exchange area is larger than that of the parallel flow type, it is also known as the full-evaporative condenser.

According to the installation position of fan, it can be divided into suction type (suction type) and pressure-type (blower type).The pressure-type blower is installed at the bottom of the equipment, the fan in operation will make the box of the negative pressure, so that the air is sucked into the box, and Then the heat and mass exchange is carried out with the heat exchange coil. While the suction-type blower is at the top of the equipment, the heat transfer effect will be better than the pressure-type's, but the air blower outlet of the hot and humid atmosphere is easy to cause corrosion to the fan.

According to the cool method, evaporative condenser can be divided into direct type (DEC) and indirect type (IEC).Dec is characterized by the cool water enthalpy will remain unchanged, cool water and air due to heat transfer, its temperature will be reduced, but the air moisture content will gradually increase; IEC is the use of DEC in the process of humid air and low temperature air for cool air, the temperature of the cool water and air is reduction, but the air's moisture content is unchanged.

3. Research progresses

The evaporative condenser was introduced by Professor Peilin Chen from Tongji University in the 1980s. In recent years, with the further research on the evaporative condenser, there are certain developments in theoretical basic research, mathematical modeling, simulation research and applied basic research.

There are many factors influencing the heat transfer effect of evaporative condenser. The factors affecting the heat transfer system are the shape of the heat exchange tube, the shape and the thickness of the heat transfer sheet. Wind system impact factors: the face velocity of wind, different inlet direction, angle and area of wind, etc. Air inlet parameters: Wet bulb temperature, dry bulb temperature, relative humidity, air flow, etc. Influencing factors of water system is nozzle shape, spray density, the distribution of water film on the surface of the heat exchange coil, the distance between the nozzle and the heat exchange system and so on. The impact on other factors: the thickness of scales, corrosion of equipment and so on.

3.1 Experimental researches

Adel. A. [1] this paper presents an experimental study to enhance the performance of a small air condition (A/C) system by mean of direct evaporative cooling method. A setup of cooling system is designed to simulate extremely hot weather where the dry bulb temperature (DBT) reaches the vicinity of 55 ◦C which represents the highest possible weather temperature that was recorded during summer [2] The improvement of coefficient of performance and reduction of energy consumption of a split air conditioning system. When retrofitted with evaporative cooling in the condenser of split air conditioner is reviewed in this paper. The condensing unit is retrofitted with a cellulose corrugated pad. Ian et al. [3] used CFD software to simulate the flow of cool water and air into the corrugated packing and studied the flow field characteristics and heat transfer characteristics.
Li et al. [4] studied the influence of spraying water amount and the face velocity of wind on the flow resistance of the evaporative condenser in the way of the whole bundle water distribution and compared with the conventional concentrated water distribution method, it is believed that the total bundle water distribution method in the refrigeration system can reduce about 2% less than the conventional method. Zhu and Xie et al. [5] have studied 2 new types of nozzles with shunt platforms and shunt slots. A two-dimensional model is established by using CFD software to simulate its water spraying process, besides, the authors also use CFD software to predict the influence of different inlet directions on the flow field of evaporative condenser and studied the flow field characteristics of single- side inlet air, double -side inlet air and three-side inlet air [6]. Shen and Zhang [7] studied the effects of the face velocity of wind and spray density on the heat and mass transfer of evaporative condensers in the countercurrent condition. Pan [8] designs a countercurrent type evaporative condenser that can regulate the amount of fresh air. Chen and Zeng et al. [9] analyzed the heat and mass transfer of evaporative condenser by micro -element method, and the variation rule of external membrane temperature, heat flux temperature and air parameter in heat exchange tube under two kinds of tube bundle structures is studied by simulation software. Foreign more famous the enterprises of evaporative condenser mainly have America's Evapco Inc, the Swedish Alfa Laval, and the Trans Alta Energy Company of Canada and the Baltimore Aircoil Company (BAC) of the United States and so on. America's Evapco Inc studied and developed a new type of ATC evaporative condenser, the biggest improvement is that no additional configuration of cool towers and circulating pumps, eliminating the cool towers, system pumps, water pump rooms, circulating tanks, ancillary pipe valves costs [10]. In addition, the BAC Company designed a unique CXV evaporative condenser, its spray water flow is most of the traditional evaporative condenser twice times, and the unique heat exchanger system can make the pump in the larger flow of water without increasing power.

3.2 Researches on Plate Evaporative Condenser

For the plate-type evaporative condenser, Wei and Chen et al. [11] established a mathematic model of the countercurrent heat and mass transfer process, and analyzed the influence of air parameters and water flow on its performance. Jane and Ren et al. [12] focused on the board outside the water - air heat transfer performance, and summed up the calculation of correlation. Dai [13] established a gas-water two-phase flow model and used fluent software to simulate the velocity field, pressure field, temperature field and steam distribution. Jian and Dai et al. [14] studied the relative humidity of air on the heat transfer performance. Wu and Liu et al. [15] studied the effects of different heat exchange plate types and spray density on heat transfer performance. Gong and Liu [16] studied the plate configuration, spray water spray density, air inlet velocity and other factors on the gas-liquid two-phase flow characteristics and heat transfer performance.

3.3 Mathematical model research

For design methods of the traditional evaporative condenser, Yin and Wang et al. [17] proposed a new -improved temperature drop method, and calculated the same data using two methods respectively and got the error range of the two methods, where found that the improved temperature drop method can make the heat transfer area error range less than 5%. Jiang [18] studied the heat transfer coefficient of water film outside the tube, proposed a new dimensionless quantity group and heat transfer coefficient of outside the tube, which has a wider application range correlation. Ma et al. [19] proposed a new-double tube type evaporative condenser and tested its performance. The effects of heat flux density, air supply volume and circulating water volume on its heat transfer coefficient were analyzed. Wang and Huang. [20] Who combine riser indirect evaporative cooler, direct evaporative cool filler and condensate coil combination, put forward higher condensing efficiency of the composite evaporative condenser.

3.4. Industrial Researches

For the evaporative condenser water system, the Beijing Coal Mine Engineering Co., Ltd. designed a cool water energy-saving automatic control system, which can realize the cool water circulation, supply and cool tower automatic opening and closing according to the water level and temperature [21] Matsushita Compressor Co., Ltd. proposed a new circulating recycling water supply system for the disadvantage of own pump [22]. Zhejiang Wanxiang Technology Co., Ltd. and Shanghai Polytechnic University have worked out a high-efficiency and energy-saving evaporative cool (condensing) device, which can change the water sprayed cloth to directional water distribution, and can also eliminate the shower noise completely. Luoyang Longhua Heat Transfer Technology Co., Ltd. independently researched and a kind of high and efficient compound evaporative cool (condensing) technology, which was also selected as the key national energy conservation technology promotion and distribution directory.

4. Research Progress in Foreign Countries

4.1. Mathematical model research

Foreign studies are much earlier than the domestic and have a lot of advanced technology. In the researches of mathematical models: Qureshi and Zubair [23] studied the mathematical model of the evaporative condenser (cool) and conducted a thorough design and evaluation analysis. Jahangeer and Tay et al. [24] used finite difference method to simulate and analyze the heat transfer coefficient of single straight tube of evaporative condenser. Islam and Jahangeer et al. [25] established a detailed theoretical model based on the fluid-liquid flow characteristics and thermodynamic theory in order to analyze the heat and mass transfer process of evaporative condenser, and the simulation results agree well with the experimental data. Paulo et al. [26] studied the heat and mass exchange process of small-scale evaporative condensers.

4.2. Simulation Researches

In the research of control technology, the evaporative condenser can be modeled by using technical software such as Artificial neural Network (ANN), Adaptive Neuro-fuzzy Inference system (ANFIS) and ANSYS FLUENT. Such as Abbassi and Bahar [27] used the ANN to establish the thermal model of the evaporative condenser under both steady-state and transient conditions to control its thermal capacity, understand its dynamic process and predicting its preset output value. The results show that the ANN controller has the potential to replace the PID controller of the traditional thermodynamic system. Ertunc et al. [28] also established an Ann's application that is suitable for the prediction performance of evaporative condensers. The experimental data validated the analysis method of Peterson et al. [29]. Fiorentino and Starace [30] used the software ANSYS FLUENT to simulate the flow of water film on the surface of the evaporative condenser heat exchange coil and studied the heat and mass transfer characteristics, they established the two-dimensional numerical value and analyzed the influence of the pipe arrangement on the flow process [31]. Similarly, Kabeel et al. [32] and Mahmud et al. [33] conducted an in- depth study of their flow processes. Fiorentino et al. [34] also studied the combined effects of dry bulb temperature and relative humidity in air parameters on evaporative condensation performance. Fiorentino and Starace [35] Refrigerator has become an essential commodity rather than luxury item. It is one of the home appliance utilizing vapour compression cycle in it process. Performance of this system becomes main issue and many researches are still ongoing to evaluate and improve efficiency of the system. This paper presents effect of evaporative condenser on COP of domestic refrigerator

4.3. Applied Basic Research

Foreign more famous the enterprises of evaporative condenser mainly have America's Evapco Inc, the Swedish Alfa Laval, and the Trans Alta Energy Company of Canada and the Baltimore Aircoil Company (BAC) of the United States and so on. America's Evapco Inc studied and developed a new type of ATC evaporative condenser, the biggest improvement is that no additional configuration of cool towers and circulating pumps, eliminating the cool towers, system pumps, water pump rooms, circulating tanks, ancillary pipe valves costs [36]. In addition, the BAC Company designed a unique CXV evaporative condenser, its spray water flow is most of the traditional evaporative condenser twice times, and the unique heat exchanger system can make the pump in the larger flow of water without increasing power.

5. Summary and Prospect

The development of World economy and the continuous improvement of market demand, saving energy and environmental protection has become the goal of our continuous development and pursuing. Evaporative condenser with its strong performance advantages will gradually become the main force of evaporative cooling device.

We should constantly improve the theory and develop into a complete knowledge system, which includes design scheme and theoretical calculation accordingly. The rational distribution of water quantity and air volume is also main content of our future study in order to achieve the most suitable ratio of wind-water, so we can consider using simulation software to predict beforehand to reduce a lot waste of work; In order to enhance the heat transfer effect of heat exchanger coils, one of the research points is to consider combining nanometer technology and add nanometer material to the surface of the coil tube, in addition to consider adding some nanometer materials to the refrigerant to improve the performance of the refrigerant. These are the direction we need to continue to study.

References

[1] A.Adel,J.Karim Eidan. Enhancement of the Performance Characteristics for Air-conditioning System by Using Direct Evaporative Cooling in Hot climate. 9th International Conference on Applied Energy, ICAE2017, 21-24 August 2017, Cardiff, UK

[2] M. Prajapati, Dr.A. Choube. Enhancement the Performance of Condenser of Split type Air Conditioning System by using Evaporative Cooling. International Journal of Engineering Sciences & Research Technology [398-403].

[3] Z.X. Zhao, Y.B. CAI, Y.F Zhang. 3D Numerical Simulation of Film Formation on Inclined Oval Tube Water Film Evaporative Condensers [J]. Chemical Engineering & Machinery, 2017, 44(3): 328-333.

[4] Q.F. Jian, C.Y. Dai, Q. Ren, et al. Analysis on Flow Field and Heat Transfer of Corrugated Filler Used in Evaporative Condenser[J]. Journal of Refrigeration, 2014, 35(3): 90-95.

[5] T.Y. Li, X.P. Ouyang. Experimental Study on Air Flow Resistance of an Evaporative Condenser with Water Distributed on Every Tube [J]. Journal of Refrigeration, 2014, 35(2): 30-35.

[6] J.L. Zhu, J. Xie, J.F. Wang, et al. Numerical simulation and test on nozzle spraying uniformity in evaporative condenser[J]. Transactions of the Chinese Society of Agricultural Engineering, 2014(19): 38-47.

[7] J.L. Zhu, J. Xie, J.F. Wang, et al. CFD simulation of airflow distribution with different inlets in evaporative condenser [J]. Food & Machinery, 2015, 31(3): 87-92.

[8] J. Shen, C. Zhang, K.L. Lu. Experimental investigation of heat and mass transfer in evaporative condenser [J]. Cryogenics, 2015(1): 45-48+68

[9] H.K. Hong. Adjustable fresh air type evaporative condenser air guide device [J]. Technology and Economic Guide, 2016(25): 41-42.

[10] L.C. Chen, Y.H. Zeng, Y.Y. Jiang. Modolling and simulation of falling film evaporate condenser [J]. Refrigeration and Air-conditioning, 2015, 15(07):82-88.
[11] L. Tang, Z. Tang. Energy-saving application of ATC model evaporative condenser [J]. Shanghai Energy Conservation, 2014(9): 30-32.
[12] G.S. Wei, L. Chen, B. Li, et al. Model Analysis on Heat and Mass Transfer Process in Plate-Type Evaporative Condenser[J]. Electric Power Construction, 2014, 35(6): 18-21.
[13] Q.F.Jian, Q. Ren, C.Y. Dai, et al. Theoretical Analysis and Experimental Investigation of Heat Transfer in Spraying Plate-type Evaporative Condenser [J]. Journal of South China University of Technology (Natural Science Edition) , 2014, 42(4): 46-51.
[14] C.Y. Dai. Study on Flow Characteristics and Heat Transfer of Bulge-plate Evaporative Condenser [D]: South China University of Technology, 2015.
[15] Q.F.Jian, C.Y. Dai, Q. Ren, et al. Experimental Study on Effect of Inlet-Air Relative Humidity on Heat Transfer Performance of Plate-Type Evaporative Condenser [J]. Electric Power Construction, 2015, 36(3): 94-98.
[16]] X.H. Wu, L.J. Liu, X. Liu, et al. Experimental study on the water film flowing characteristics of the internal fin-plate evaporative condenser[J]. Chemical Industry and Engineering Progress, 2017, 36(6): 2017-2022.
[17] Y. Gong, X. Liu, Y.N. Yang, et al. Characteristics of Falling Film Flow and Heat Transfer in Internal Fin-plate Evaporative Condenser [J]. Journal of Refrigeration, 2016, 37(4): 20-26.
[18] K.J. Yin, R.Y. Wang, J.X. Wu. New design calculation method of evaporative condenser [J]. Refrigeration and Air-conditioning, 2014, 14(4): 21-23.
[19] Y.Y. Jang. A Thesis Heat and Mass Transfer Research of Water Film Evaporative Air Cooler and Design Program Development [D]: Huazhong University of Science & Technology, 2014.
[20] R.H. Ma, R.J. Ma, Z.Y. Wang. Study on the New Type Tube-in-Tube Evaporative Condenser Performance [J]. Bulletin of Science and Technology, 2015(7): 122-125.
[21] J. Wang, X. Huang, X.Q. Su. The Optimal Design of the Evaporative Condenser [J]. Refrigeration & Air Conditioning, 2016, 30(5): 552-556.
[22] H.W. Shi. Design of automatic energy saving control system of cooling water evaporative condenser [J]. Industry and Mine Automation, 2014, 40(08):107-109.
[23] L.Y. Chen, L.L. Shao. Study on water cycle system of evaporative condenser [J]. China Appliance Technology, 2016(1): 76-77.
[24] Qureshi BA, Zubair SM. A Comprehensive Design and Rating Study of Evaporative Coolers and Condensers. Part I. Performance Evaluation [J]. International Journal of Refrigeration, 2006, 29(4): 645-658.
[25] Jahangeer K A, Tay A A O, Islam M R. Numerical investigation of transfer coefficients of an evaporatively-cooled condenser [J]. Applied Thermal Engineering, 2011, 31(10):1655-1663.
[26] Islam M R, Jahangeer K A, Chua K J. Experimental and numerical study of an evaporatively-cooled condenser of air-conditioning systems[J]. Energy, 2015, 87:390-399.
[27] Junior I C A, Schneider P S. Consolidated experimental heat and mass transfer data base for a reduced scale evaporative condenser [J]. International Journal of Refrigeration, 2016, 66:21-31.
[28] Abbassi A, Bahar L. Application of neural network for the modeling and control of evaporative condenser cooling load [J]. Applied Thermal Engineering, 2005, 25(17):3176-3186.
[29] Ertunc H M, Hosoz M. Artificial neural network analysis of a refrigeration system with an evaporative condenser [J]. Applied Thermal Engineering, 2006, 26(5):627-635.
[30] Peterson D, Glasser D, Williams D, et al. predicting the performance of an evaporative condenser [J]. Journal of Heat Transfer Transactions of the ASME, 1988, 110(3):748-753.
[31] Fiorentino M, Starace G. Numerical and Experimental Performance Analysis of Evaporative Condensers[C]// Conference of the Italian Thermal Machines Engineering Association, Ati. 2016.
[32] Fiorentino M, Starace G. Numerical investigations on two-phase flow modes in evaporative condensers [J]. Applied Thermal Engineering, 2016, 94:777-785.
[33] Kabeel A E, Bassuoni M M, Abdelgaied M. Experimental study of a novel integrated system of indirect evaporative cooler with internal baffles and evaporative condenser [J]. Energy Conversion & Management, 2017, 138:518-525.
[34] Mahmud M A, Macdonald B D. Experimental investigation of interfacial energy transport in an evaporating sessile droplet for evaporative cooling applications [J]. Phys.rev.e, 2017, 95(1).
[35] Fiorentino M, Starace G. Experimental Investigations on Evaporative Condensers Performance[C]// Aicarr International Conference, 10-11 May. 2017.
[36] Gurav, P. Kainge Experimental Study of Effect of Evaporative Condenser in Domestic Refrigerator International Journal of Engineering Sciences & Research Technology [398-403].