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Study on the Application of the Double-membrane Technology in Dealing with Circulating Cooling Blow-off Water to Prepare the Boiler Feedwater

Lei Qu & Liang Wang
The Key Lab of Hollow Fiber Membrane Materials and Membrane process of Ministry of Education
Tianjin Polytechnic University
Tianjin 300160, China
College of Material Science and Chemistry Engineering, Tianjin Polytechnic University, Tianjin 300160, China
Lin Shao
Tianjin Electric Power Research Institute, Tianjin 300160, China
Peng Qi
Tanggu Environmental Protection Monitoring Center Of Tianjin, Tianjin 300450, China
E-mail: kemboy@163.com

Abstract

In the article, combining with the engineering practice, we study that the membrane technology (microfiltration (MF) + reverse osmosis (RO)) is applied to pre-demineralization of the circulating cooling wastewater back to boiler feedwater by the heat power plant. The operation parameters of the reusing system were obtained through the actual test and the experimental results show that the technology which uses MF as pretreatment process of RO can meet the requirement of the RO inlet water quality with above 98% of the demineralization rate of the RO system, which has achieved good economic and social benefits.

Keywords: Membrane separation, Reclaimed water reuse, Circulating cooling blow-off water, Boiler feedwater

The heat power plant is one of main industrial consumption users, and it is one of main waste discharge users. The water consumption in the circulating cooling water system occupies above 80% of the water consumption of the whole plant, so the reuse of the circulating cooling blow-off water is imperative under the situation (Sha, 2001, P.50-52). To better use the circulating cooling blow-off water and enhance the reuse rate of the water are effective approaches to reduced the practical industrial water consumption and realize the zero draining of wastewater. To take the circulating cooling wastewater of the power plant as the boiler feedwater is one of good water saving methods, but the salt content of the circulating cooling blow-off water is always 2-5 times than the circulating complementary water, and if we take the water with high salt content as the water source of the boiler feedwater and still adopt traditional ion exchange technique, so we need frequently implementing acid and alkali regenerations and let a great lot acid and alkali waste fluids, which would enhance the running costs and pollute the environment. As a sort of new liquid separation unit operation technology, the membrane separation technique is more and more applied to the pre-demineralization system of the circulating waster water in foreign and domestic heat power plants because of its many advantages such as high efficiency, environmental protection, few floor space, low power consumption, high automatization and convenient maintenance.

1. Inlet water quality and process flow

1.1 Inlet water quality

Tianjin Chentangzhuang Heat Power Plant constructed 2×300MW electric generating set in the third-term project, and it successfully applied the MF as the pretreatment of RO in the preparation of the boiler feedwater. The water source includes the circulating cooling wastewater from the first-term project and the second-term project, and the complementary water of the first-term circulating water and the second-term circulating water is the sea water and river water, and the weight concentration of the circulating cooling blow-off water is 2.5.

1.2 Process flow

The main water source entering into the membrane system is the circulating cooling wastewater, and the complementary water sources are the sea water and river water, and the emergent complementary water source is the tap water, so the water source supply security can be ensured when the boiler feedwater increases.

2. Running of MF-RO system

2.1 MF pretreatment system

The circulating cooling wastewater possesses many characteristics such as high turbidity and high salt content, and it can not directly enter into the membrane system and it needs the pretreatment before entering into the membrane. Sterilize the circulating wastewater by add ClO_2 in the raw water box, and because the inlet temperature of the MF membrane requires 20℃~35℃, so we can properly enhance the inlet water temperature and reduce the water viscidity, enhance the fluxes of the high MF membrane and RO membrane and reduce the inlet membrane pressure (Yu, 2006, P.57-63). To ensure the proper temperature of the inlet water and the successive flocculation effect, especially in the cold winter, the raw water heater is set up in the system.

Through dynamically simulating in the former phase, the dosages of the flocculating agent and coagulant aid are confirmed in the mechanical accelerating pool. The flocculating agent is PAFC and the dosage is 50mg/L, and the coagulant aid is the polyacrylamide, and its dosage is 1mg/L. The raw water through primary turbidity removal enters into the air cleaning strainer which is the double-medium filter, and in the filter, the bottom layer is the quartz sand and the upper layer is the anthracite to eliminate the colloid and suspended substance in the raw water and reduce the inlet turbidity and fulfill the MF inlet requirement. The circulating cooling wastewater after membrane pretreatment enters into the clean water box and waits for entering into the membrane system.

The equipment before MF is the Israel ARKAL plate filter, and the filtering precision is 55μ, and it can prevent the bigger grains enter into the MF system and mechanically scuff the membrane surface and ensure the long-term stable running of the MF system.

2.2 MF unit

The MF membrane is the UNA-602A hollow-fiber membrane made by Japan Asahi Kasei Corporation, and the filtering precision is 0.1μ. Comparing with traditional products, the new-generation PVDF hollow-fiber membrane possesses many characters such as high mechanical intension, anti-oxidation, anti-pollution and high flux, and it adopts low-pressure operation, back flush, air water washing and other new technologies to make the MF membrane can keep stable performance in the wastewater medium with strong pollution.

There are many domestic power plants which use the clarifying and filtering as the RO pretreatment. The water source of Tianjin Junling cheng Power Plant was sea river water, and because the pretreatment technique was not proper, the SDI of the yielding water had exceeded 4-5 for a long time, and the import RO membrane was discarded as useless only in a half year, and the domestic RO membrane was discarded as useless only in three months. There are RP membrane damages and useless RO equipments in Shijingshan Electric Power Plant, Huaneng Dezhou Thermal Power Plant, Dagang Electric Power Plant and Hengshui Electric Power Plant all induce because of bad water quality of RO. The yielding water quality of RO pretreatment directly influence the use life, the cleaning cycle, water yield and running cost of RO. The unqualified RO pretreatment always make the RO equipments can not run normally, deteriorate the yielding water, reduce the water yield and membrane life. Many practical examples and researches indicated that one of the pollution sources of RO is the colloid grains induced by the bad RO pretreatment, and the possibility of this sort of pollution can be denoted by the index of SDI. The influences of various yielding water SDI indexes of pretreatment to the RO membrane performance are seen in Table 2.

There are 2 sets of MF equipments in the system, and the power of the single MF equipment is $150m^3/h$, and single MF equipment includes 56 PVDF membrane components. The crustaceous material of the hollow MF membrane UNA-620A is ABS resin, and the MF component size is 2338L×165Φ. The outside diameter of the hollow fiber is 1.2mm, and the inside diameter is 0.7mm, and the exterior surface of the hollow fiber is the separation layer, i.e. the exterior pressured hollow fiber membrane.

2.3 RO unit

The system has 2 sets of RO equipment which has one class and two stages. Each set of equipment has 21 pressure vessels which are arranged by 2:1, and the quantity of the membrane components are 126. The water yield of each RO system is $100m^3/h$, and the design reclaimed rate is controlled in 70%~75% regulated by the membrane component manufacture, and each RO system equips 126 US Dow BW30(LE)-440(FR) membrane components, and the effective membrane area of every membrane component is $41m^3$, and they are respectively fixed in 21 pressure vessels. The RO is distributed by two parts. The first part of wastewater enters into the second part as the inlet water, and the first part yielding water and the second part yielding water combine and enter into the freshwater box, and enter into the mixed bed, and the second part wastewater enters into the neutralization pool. The mixed bed is regenerated in the body, and the yielding water is supplied by the demineralization box.

3. Prevention of membrane pollution

3.1 Prevention of the MF membrane pollution

After set up the yielding cycle of 1700s, implement 60s air back flush and 60s flush. When implementing back flush, the compressed air should be added to increase the shaking of the membrane and shake off the contaminations. When preparing the water, add 0.2-0.5ppm NaClO to kill the biological colloids and microorganisms in the water. In the next day, increase the EFM dosage of 500-900ppm NaClO. When the membrane penetration pressure difference achieves 0.15-0.2Mpa, add 1000-3000ppm NaClO+1% NaOH, and add 2% of hydrochloric acid. Through above measures, the membrane pollution can be effectively prevented, and the continual and safe running of FM can be ensured and the safe running of the RO equipment can be further ensured.

3.2 Prevention and cleaning of RO membrane pollution

The RO membrane component material is the polyether sulphone which is the oxidated substance, and it needs adding Na_2SO_3 in the membrane raw water to eliminate NaClO. And at the same time, we should ensure SDI≤3. When the equipment stops in the short term or the equipment suddenly stops pump and when the equipment restarts, the equipment should be flushed.

In the process of RO, when any one of following instances occurs, we advise chemical cleaning.

(1) When the inlet parameter is certain, the conductance of the penetration liquid increases obviously.

(2) When the inlet water temperature is certain, and the export end pressure of the high-pressure pump increases above 8%~10%, the membrane flux can be kept invariably.

(3) When the feed-in flow velocity and temperature are certain, increase 25%~50% of the inlet and outlet pressure difference of the RO equipment.

(4) Run for three months in the bad inlet water condition and run for six months in the normal inlet water condition, the normal cleaning should be implemented.

Otherwise, when the RO system stops, we must periodically clean the membrane to keep the RO membrane wet and prevent the growth of the microbes (Hou, 2002, P.45-47).

The cleaning methods of RO membrane can be divided into three sorts, i.e. the physical method, the chemical method and the physical-chemical method. In these three methods, the chemical method is used most extensively in the cleaning of the RO membrane, and its cleaning effect is decided by many factors such as the PH of the cleaning liquid, the temperature, the flow velocity and the cycle time, and one sort of cleaning liquid can be successful in some cleaning systems, but it can not ensure to be successful in other systems. For the chemical cleaning, according to testing and analyzing results of the contaminations, proper cleaning liquids can be selected and the cleaning liquid should be compatible with the type of the membrane and should not corrupt the system. Table 5 shows general selection principles.

The practical cleaning plans should be implemented according to many comprehensive factors such as the temperature of the RO membrane, the range of PH value and the endurance to the cleaning liquid.

4. Conclusions

(1) Through six months' practical running, it is feasible for the factory to use the circuiting cooling wastewater to prepare the boiler feedwater in theoretical design, and the effect is vey good, and it can reduce the pollution and increase the effect, and obtain good economic benefit and the environmental benefit. For the reclaimed water treatment, the double-membrane can be applied in not only the reclaiming of the urban living wastewater, but also the reclaiming of the industrial wastewater, and it can make the drain of the production process to be the reliable demineralization water source.

(2) MF can eliminate most suspended substances, organic things and grain substances and the yielding water turbidity is smaller than 0.1NTU, which can largely improve the water quality of the RO inlet water and ensure the successively safe running of the RO.

(3) The application of the double-membrane reduce the demineralization pressure of the mixed bed, reduce the regeneration period of the mixed bed acid and alkali, and reduce the discharge of the acid and alkali waste liquid, and produce economic an environmental benefits.

(4) The double-membrane method with many characteristics such as high automatization degree, controlled program and few floor spaces can largely reduce operators' labor intension and further enhance the running level and the automatization degree of the whole water treatment technique.

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Table 1. Water quality report of the circulating cooling water

Item	mg/L	Item	mg/L
K^+	32.1	total iron mg/L	0.79
Na^+	2566	full hardness mmol/L	15.56
Ca^{2+}	129.88	total alkalinity mmol/L	6.71
Mg^{2+}	297.5	enolphthalein alkalinity mmol/L	0.89
Ba^{2+}	0.21	all-silica mg/L	0.83
Sr^+	2.0	turbidity	14
Cl^-	3265.16	suspended substance mg/L	179
SO_4^{2-}	153.59	total dissolved solid mg/L	7289
HCO_3^-	250.1	electrical conductivity μS/cm	6500
CO_3^{2-}	0.89	pH	8.6
NO_3^-	6.0	COD mg/L	201

Table 2. Influences of SDI index to the RO membrane performance

Pretreatment	SDI index	Use life of membrane/ year	Normal permeation rate %
hyperfiltration and MF	<1	7~8	+40*
MF	1~2	3~5	benchmark
Cleaning, multiple-layer filtering and exact filtering	3~5	1~2	-10*
Ordinary tap water	>5	<1	-10~+20*

Note: 1. "*" denotes the water yield of the membrane under the normal situation.

2. The permeation rate value is the relative value based on the normal permeation rate of MF, +40% denotes the value is 40% higher than the MF permeation rate, and -10% denotes the value is 10% lower than the MF permeation rate.

Table 3. The running result of 1# FM system

Date	Inlet flux t/h	Inlet pressure MPa	Yielding pressure MPa	Pressure difference MPa	Yielding water flux t/h	Turbidity of yielding water NTU	Water temperature ℃
10.14	147.56	0.151	0.082	0.069	139.36	0.029	18.3
10.18	146.09	0.150	0.080	0.070	139.38	0.027	17.4
10.23	154.45	0.140	0.073	0.067	144.17	0.030	16.8
10.27	160.85	0.160	0.086	0.074	151.14	0.024	16.3
11.02	163.77	0.156	0.080	0.076	152.45	0.026	14.5

Table 4. The running result of 1# RO system

Date	Inlet pressure MPa	Pressure difference of the first part MPa	Pressure difference of the second part MPa	Yielding water flux t/h	Yielding water conductance μS/cm	Demineralization rate %
10.14	1.23	0.16	0.10	102	21.35	98.8
10.18	1.24	0.16	0.11	100	22.65	98.62
10.23	1.24	0.15	0.11	100	30.25	98.15
10.27	1.23	0.16	0.12	103	29.12	98.23
11.02	1.24	0.16	0.11	101	26.3	98.6

Table 5. General cleaning principles of the membrane cleaning liquid (B Tansel, 2000, P.7-14)

Contamination	Selection principle of cleaning liquid
Calcium dirty	Various acids combining with EDTA
Metal hydrate	Oxalic acid and citric acid combining with EDTA and surface active agent
SiO2 and other colloids	In high pH, use NH4F combining with EDTA and special cleaning liquids such as STP and BIZ
Biological contaminations	In high pH, use BIZ or EDTA to wash, and use Cl_2, $NaHSO_3$, CH_2O, H_2O_2 or peroxyacetic acid to wash
Organic matter	Use IPA or other special reagents combining with the surface active agent
bacillus	Use Cl2 or formaldehyde solution to wash

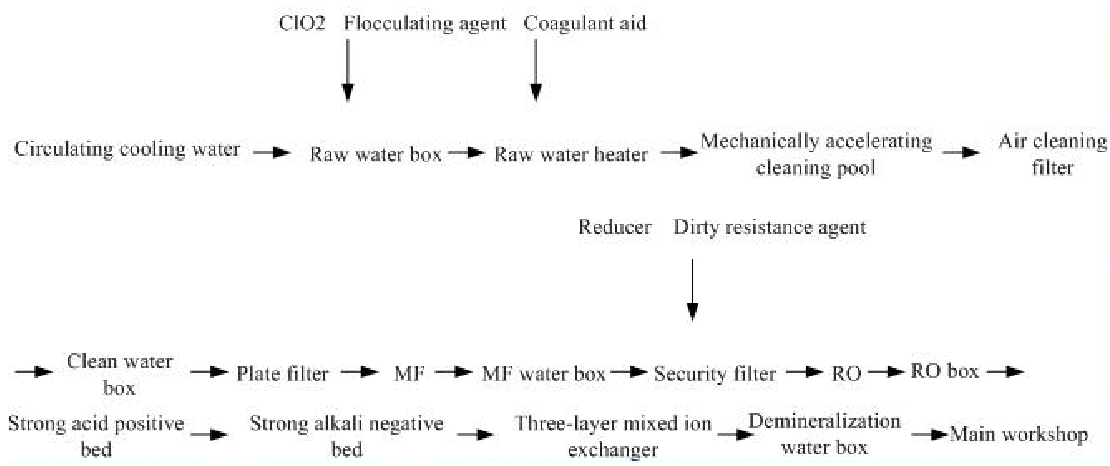

Figure 1. Process flow