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Simulation of Multi-stage Flash (MSF) Desalination Process

Lian-ying Wu, Sheng-nan Xiao, Cong-jie Gao
College of Chemistry and Chemical Engineering, Ocean University of China, Shandong, Qingdao 266100, China

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ABSTRACT

MSF seawater desalination has become an important technology to solve the scarce of fresh water resources in the world. But the high energy cost is the bottle-neck of extendibility and application. In this paper, the principle of MSF is analyzed and the single flash stage is divided into several elementary unit operations. The Aspen Plus is adopted to simulate MSF desalination process. The effect factor of MSF system, such as the feed seawater temperature, the top brine temperature（TBT） and the stage number, is investigated and the optimum operation condition is obtained.

Keywords: Seawater Desalination; MSF; Process Simulation

1. Introduction

The fresh water resource is one of the most important factors which constrain the economic development, social progress and human survival. Currently, there are more than 100 countries and regions, in where the fresh water is shortage, about 1.5 billion people can not get the clean drinking water, 2.0 billion people are living without safe water, and the consumption of water is increasing at a rate of 4% per year [1,2]. China is one of the countries that the United Nations recognized as the 13 most water-poor countries, per capita fresh water resources is only 1/4 of the world average level, and the temporal and spatial distribution of freshwater resources is uneven. And the lacking is characteristic with both at resources and water quality [3-5]. Water scarcity has become a major bottleneck that constraints the world's sustainable economic development [6].

Desalination has become recognized as an effective measure to solve the water shortage [1]. However, high energy consumption is one of the major bottlenecks to limit its promotion and application. Therefore, it is important significance to seek methods to reduce the desalination energy consumption. This paper is trying to use Aspen Plus software to simulate the MSF desalination process and analyze the effects of the operating parameters to the MSF desalination system. At the same time, the method of reducing energy consumption is provided as reference to the design of MSF system.

2. The Principle of MSF Desalination

The MSF system (shows in **Figure 1**) consists of three sections: heat-rejection, heat-recovery and brine heater. The heat-rejection and heat-recovery consist of a number of flash chambers (stages) connected to one another. Raw seawater first come into the heat-recovery section to condense the steam produced in the flash chamber, at the same time it is heated. Most of the water coming from the heat-rejection section return to the sea, and the remaining part will be mixed with part of the brine rejected from the last stage of the heat-rejection section; and then transported by brine circulating pump into the condenser of the last stage flash chamber of the heat recovery section. The recycling brine, which flowing along with the opposite direction of the flash brine flow direction, is heated by the flash steam producing in every flash room, and the flash steam is condensed. The heated circulating brine coming out from the condenser tube of the first flash chamber is transported into the brine heater and is further heated to a specified temperature, which is the top brine temperature (TBT). And then it flows into the lower level of the first flash chamber, and the circulating brine begins to progressively flash along per flash stage. The flashed steam will be condensed in the condenser tube, and then it flows into the fresh water tank as product water.

3. The Simulation and Analysis of MSF Desalination Process

Performance Ratio (PR) and the rate of brine flow (RBF) are two important parameters that have a major impact on the investment costs and the operating costs of the desalination systems [10]. This paper mainly studies the influence of the feed seawater temperature, TBT and the number of flash stage on PR and RBF. Then, the expecting optimal operating conditions of the multi-stage flash desalination system is provided.

The realization of the MSF process in the Aspen Plus

MSF desalination system is composed of N-level flash units. **Figure 2(a)** represents the actual structure of a flash unit; **Figure 2(b)** shows the structural decomposition of a flash unit. The flash unit is split up into four compartments: the pre-heater, the flash chamber, the fresh water room and the steam room. Then it is very easy to be described with the Aspen Plus. The preheater in top of the flash chamber could be simulated by the HETRAN module of the Aspen Plus, the flash chamber could be used FLASH module to be simulated and the fresh water room and the steam room could be used MIXER module to be simulated. After the MSF is be transformed, the single flash unit will be constructed based on the actual logistics connection

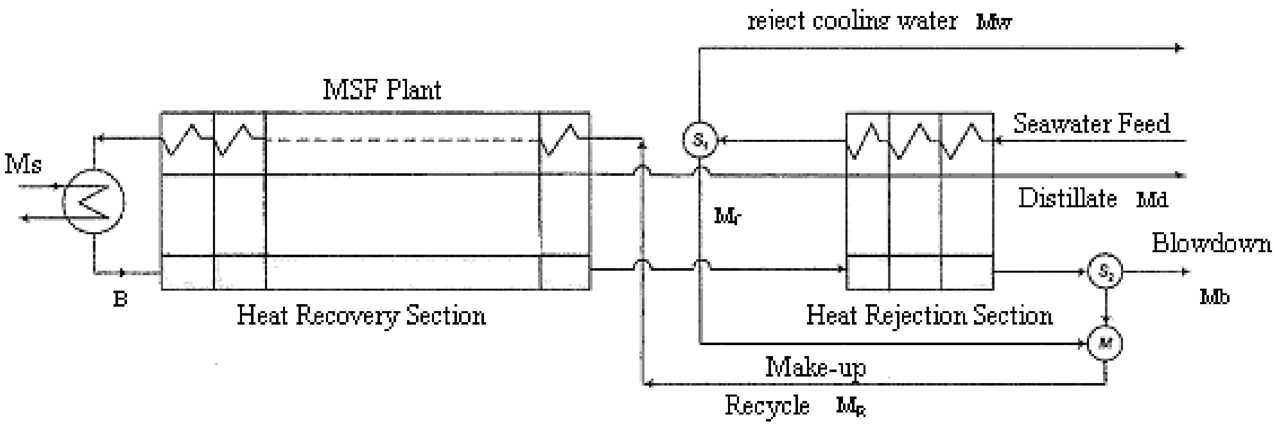

Figure 1. A circulating-brine multistage flash (MSF) desalination plant.

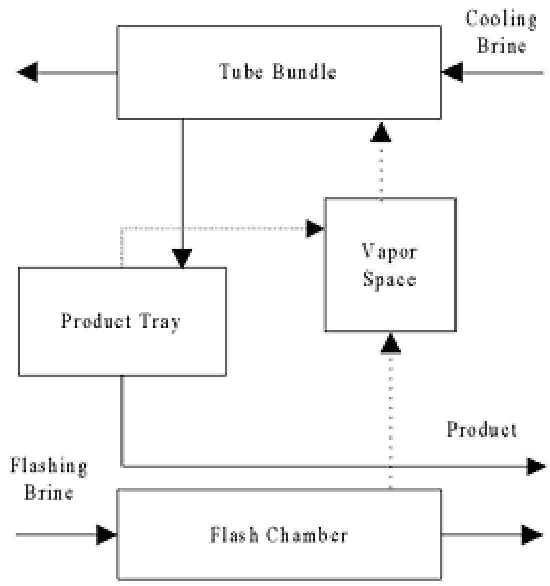

Figure 2. The structure of a single flash stage.

of the stream. Subsequently, connecting the multiple flash units sequential, the simulation of the process of MSF system is achieved in the Aspen Plus.

4. Analysis of Simulation Results

4.1. The Influence of Feed Seawater Temperature

Here, the heat recovery section and the heat rejection section are specified as 18 stages and 3 stages in the MSF system. The TBT is set to 110℃ and the freshwater production is set to 100t/h. The difference between feed seawater temperature and the rejected brine temperature is 10℃. The feed seawater temperature is varied from 10℃ to 35℃ with interval of 5℃.The vary trend of PR and RBF long the feed seawater temperature is obtained. The results are shown in **Figure 3**, **Figure 4**.

Figure 3 gives the chart of feed seawater temperature vs. PR. From the chart, the PR of the MSF system showed a gradually rising trend when the feed seawater temperature is increased. The PR of MSF system did not change significantly and over the range of 10 ~ 20℃, but it was approximately straight up between 20 ~30℃. When the feed seawater temperature goes beyond to 30℃, the changed trend of PR becomes to be gently. The chart of RBF vs. feed seawater temperature is shown as **Figure 4**. The value of RBF almost changed and the line is level when the feed seawater temperature is varied from 10℃ to 20℃. But it was rapidly increasing when the feed water temperature passed 20℃.

While the freshwater production, the TBT and the number of flash stage are specified as a constant, the lower of the feed seawater temperature, the more of the steam required to heat the brine to TBT. But when the feed seawater temperature beyond to 25℃, the temperature of circulating brine, which coming out from the first stage flash pre-heater and being heated by the multi-stage pre-heater, slowly changed. And the required amount of heating steam tends to change slowly, so the PR became relatively gentle. At the same number of flash stages, the temperature of rejected brine increased when the feed seawater temperature is increased. Because the temperature difference of between the feed seawater and the rejected brine is set to 10℃. However, the TBT is keep as an unvaried v a l u e , therefore the total difference in temperature and the stage temperature difference will be reduced simultaneously. Consequently, the producing fresh water of per unit flash stage will be decreased. In order to produce the same quantity of fresh water, the amount of circulating brine must be increased. Increasing the amount of circulating brine flowrate will make huge operating costs. Summarizing, the appropriate feed seawater temperature is about 25℃.

4.2. The Influence of TBT

Here, the heat recovery section and the heat rejection section are specified as 18 stages and 3 stages respectively in the MSF system. The freshwater production is set to 100t/h. The feed water temperature is set to 25℃ and the temperature of rejected brine temperature is set to 35℃. The TBT is varied from 80℃ to 120℃ with interval of 10℃. The simulation results are shown in **Figure 5** and **Figure 6**.

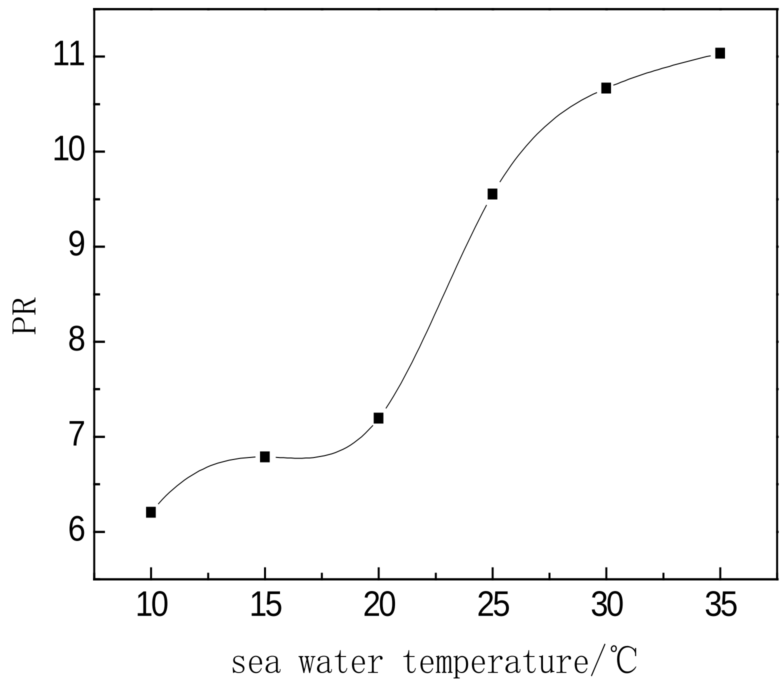

Figure 3. Effect of feed seawater temperature on the PR.

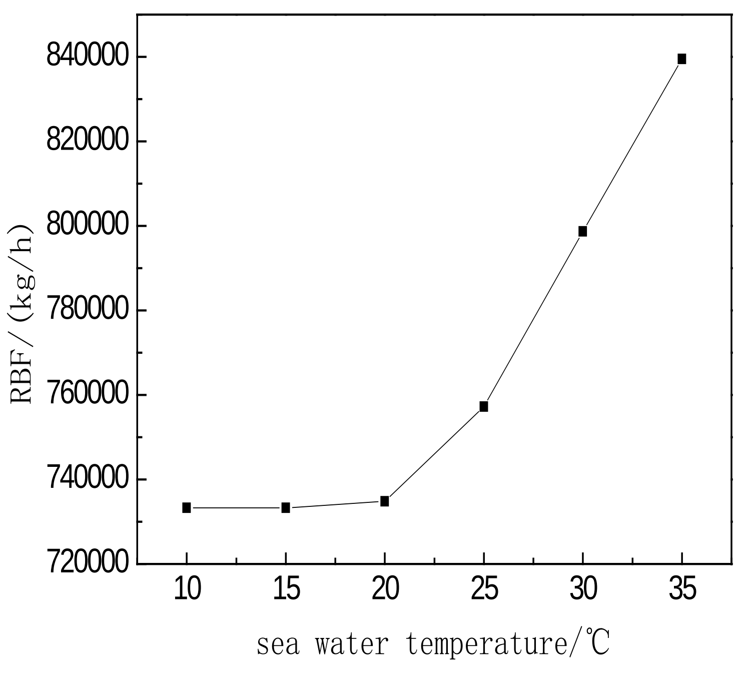

Figure 4. Effect of feed seawater temperature on the RBF.

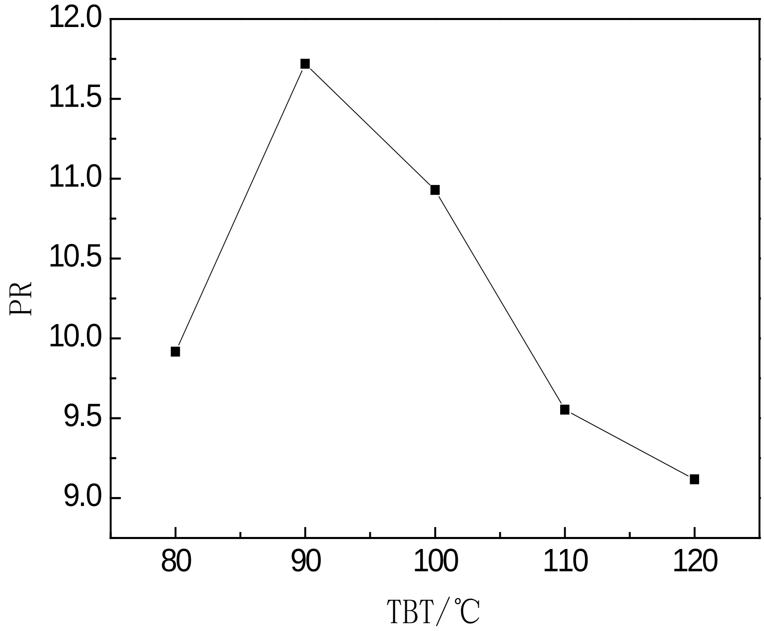

Figure 5. Effect of top brine temperature on the PR.

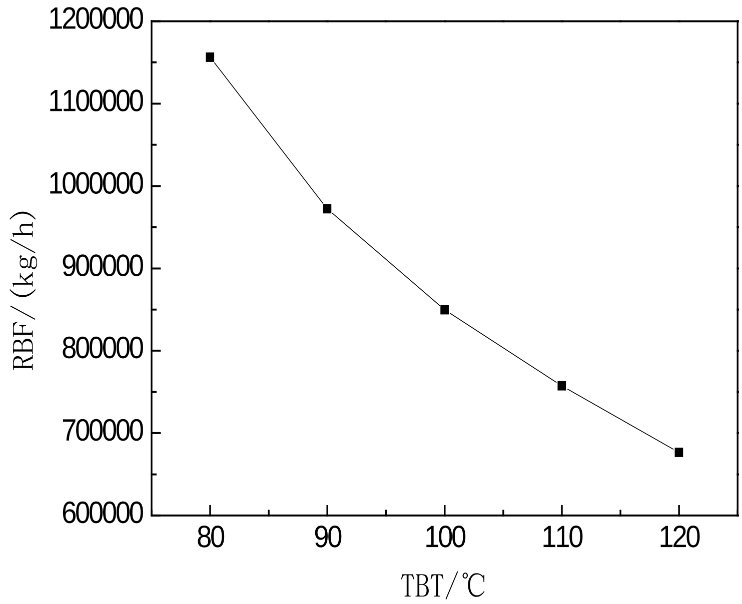

Figure 6. Effect of top brine temperature on the RBF.

Figure 5 and **Figure 6** give a PR chart of MSF and the RBF chart of MSF respectively when the TBT is changed. From **Figures 5** and **6**, the PR increased firstly and where-after decreased step by step with the TBT is increased. And the maximum value of PR is obtained at 90℃. But the RBF chart of MSF showed decreasing trend, and the reduced trend is weakened gradually while the TBT is increased. As the temperature of rejected brine is constant, the total flash temperature difference of system and the flash temperature difference of per stage were increased after the TBT is increased. With the same number of flash stage, the total amount of fresh water would be increased due to the producing fresh water quantity of single stage increased. So the RBF of MSF would be decreased to guarantee the total production of fresh water to constant. On the other hand, though the required amount of steam heating will be large on account of hoisting the TBT. But the RBF was reduced more obviously at the range of 80 ~ 90℃, so the result is that the PR increased rapidly and the required amount of steam heating reduced markedly. While the TBT is higher than 90, the amount of increasing heat steam took the more important role in influence of PR than the amount of reducing RBF. Accordingly, the PR diminished when the TBT is higher than 90.

Therefore, considering the performance ratio and operating costs, the TBT of MSF system should be between 90 ~ 110℃ appropriate.

4.3. The Influence of Flash Stage Number

In this section, the PR and the RBF influenced by the flash stage number will be discussed. The given as fellow: the TBT is 110℃, feed water temperature is 25℃, the temperature of discharged brine is 35℃ and the fresh water production is 100t/h in the MSF system. The results are depicted in **Figure 7** and **Figure 8**.

When the flash stage number is increased, the PR increased gradually, and the more the stage number is, the greater the PR is achieved. By contraries, the amount of the circulating brine showed a decreasing trend.

As the same total difference in temperature is fixed, the difference in temperature of single stage was decreasing when the number of flash stage was increased. Therefore the flashing of brine would be more close to the reversible process, and the energy loss would be reduced. At the same time, the brine pre-heater could recovery more heat and the required quantity of heating steam could be cut down. Consequently, the PR should be increased. On the other hand, the closer the brine evaporation process to the reversible process, the more the fresh water produced in an single-stage evaporation unit. To holding the same fresh water production, the number of flash stage is bigger and the required amount of the circulating brine is little. But the more stage number, the equipment will become more complexity and the investment costs will be higher. Considering the investment costs and operating costs, the number of flash stage should be more reasonable for the 20-25 level.

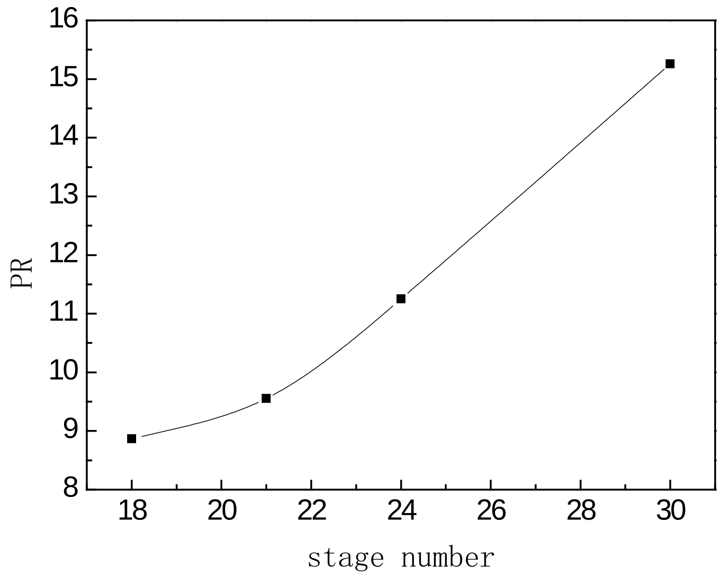

Figure 7. Effect of flash stage number on the PR.

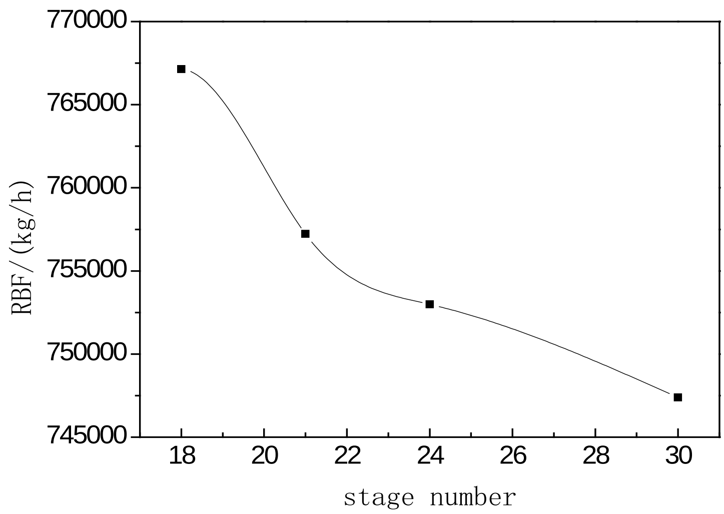

Figure 8. Effect of flash stage number on RBF.

5. Conclusions

In this paper, multi-stage flash desalination technology is analyzed. The single flash unit is divided into several basic operations, and the Aspen Plus software is used to simulate the multi-stage flash desalination process. Several influenced factor of the MSF system are discussed, such as the feed sea water temperature, the TBT and the number of flash stage. The results shown: when the fresh water production, the TBT and the number of flash stage are fixed, the lower the feed water temperature, the greater the amount of required external heating steam, the smaller the PR and the greater the amount of circulating brine. Similarly, fasting the fresh water production, the feed sea water temperature and the number of flash stage, when the top brine temperature was increased, the PR increased at first and then decreased, but the RBF was gradually reduced; With the fresh water production, the TBT and the feed sea water temperature constantly, the PR was increased gradually and the RBF was reduced gradually when the flash stage number was increasing. Synthetically, the best operating conditions of the MSF system should be selected as follows: feed water temperature is 25℃, the TBT is 90 ~ 110℃, and the number of flash stage is 20~ 25.

6. Acknowledgements

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