Design of Multi-effect Evaporator for Sewage Treatment

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Abstract. This paper takes chemical salt water treatment as an example, to describe the design process of multi-effect evaporation sewage treatment equipment. Using software to simulate and analyze the influence of different factors on the results. Using line graphs to show the results of operating conditions of Luoyang Sinopec Branch.

Introduction
Evaporation refers to the process of evaporating and concentrating the solution containing the non-volatile solute and the volatile solvent, mainly by heating to vaporize a part of the solvent in the solution [1]. The multi-effect evaporator uses the secondary steam produced in the evaporation production as the heat source of the next unit. Such as, liter film multi-effect evaporator, falling film multi-effect evaporator [2], steam recompression multi-effect evaporator[3].

Multi-effect Evaporator Design
Select Design Software and Reasons
Aspen Plus was used to establish a chemical salt water treatment system.
(1) The model physical property database is complete and suitable for more complex process simulation.
(2) Fast unit simulation is possible.
(3) With advanced calculation methods, the model can be optimized.

Setting the Composition of Salty Sewage
It is difficult to determine accurate data for these substances, such as chemical formula, content, etc. Therefore, in the modeling verification, the sewage composition needs to be simplified. In this design experiment, according to the sewage component in the sewage data of Luoyang Sinopec Branch, it is assumed that the large particle insoluble sludge has been removed. Common electrolytes such as ions and potassium ions are used as impurities, and volatile impurities are not considered at present[4].

Determination of Multi-effect Evaporator Efficiency
With the increase in the efficiency of the multi-effect evaporator, the amount of steam required is reduced and the operating cost is reduced with the same total evaporation, the equipment and infrastructure costs will increase[5]. Therefore, the multi-effect evaporation system referred to herein is three-effect evaporator.

Design Evaporator
The heat exchanger model HeatX in Aspen plus, the separator model flash and the pressure transmission module Valve represent the multi-effect evaporator.

Design Condenser
In multi-effect evaporation, using the HeatX model in the Aspen plus module library instead. The final multi-effect evaporator system is:
Figure 1. Multi-effect Evaporation System.

**Determine the Convergence Method**

The current simulation convergence method selects the traditional WEGSTEIN method.

**Module Parameter Setting**

The system parameters simulated in this paper are as follows:

| Calculation parameter | HeatX | Stream | flash | Valve |
|-----------------------|-------|--------|-------|-------|
| Hot fluid outlet gas fraction | —     | —      | —     | —     |
| Hot fluid outlet temperature | —     | —      | —     | —     |
| ingredient | —     | —      | —     | —     |
| pressure | —     | —      | —     | —     |

According to the above table, the fluid parameters of the evaporation system designed in this paper are:

| Hot stream | Cold stream | Heatx | Valve | Flash |
|------------|-------------|-------|-------|-------|
| 120°C | 60°C | 0.5 | — | 116.2°C |
| 0.3Mpa | 0.12Mpa | — | 0.07Mpa | 0.12Mpa |
| 10kg/h | 10kg/h | — | — | — |

**Model Verification Results**

After completing the above multi-effect evaporator model design work, the simulation software can be used to run the verification. Based on these data, the water generation ratio and heat exchange area of the multi-effect evaporator can be estimated.

**Simulation of the Effect of Evaporation Efficiency on the Process**

This simulation compares the water production ratios of one effect, two effects and three effects respectively. The data changes are shown in the figure 2.

It can be seen from the above figure that under the condition that other process parameters remain unchanged, the water production rate increases significantly with the increase of effect, and the heat exchange area also increases with the increase of effect. However, with the increase of evaporation units, the increase rate of water yield decreases.
Simulation of the Effect of Heating Steam Temperature on the Process

In the case where the system efficiency is three-effect, the water production ratio and heat exchange area of the system vary with the heating steam temperature as shown in the figure 3-4.

![Figure 2](image)

It can be seen from the above figure that as the temperature of the heating steam increases, the water production ratio and heat exchange area of the system decrease. The main reason is that in the heat exchange process, the heating steam is saturated steam, and the heating of the cold fluid mainly depends on the latent heat of vaporization of the steam. As the temperature increases, the latent heat of vaporization of the steam decreases, so the evaporation of the sewage decreases. At the same time, due to the increase of the temperature of the hot fluid, the temperature difference in the heat exchange process increases, so the required heat exchange area also decreases. In summary, as the heating steam temperature increases, the water production ratio and heat exchange area of the system will decrease, but the reduction of the heat exchange area is greater than the reduction of the water generation ratio. Therefore, the cost of the system can be reduced by increasing the temperature of the heating steam. If conditions permit, superheated steam can be used instead of saturated steam as the evaporation heat source, and the effect is better.

Simulation of the Influence of Feed Temperature on the Process

Under the condition that the system is three-effect, the water-making ratio and heat exchange area of the system change with the feed temperature as shown in the figure 5-6.

As can be seen from the above figure, as the feed temperature increases, the water production ratio and heat exchange area of the system gradually increase. The main reason is that the higher feed temperature means that the heat transfer amount of the temperature rise and evaporation is smaller, so in other under the condition that the conditions are constant, the evaporation of sewage will inevitably increase. At the same time, due to the reduction of the heat exchange temperature difference, the heat exchange area will increase. As can be seen from the data in the figure, the increase in the area of heat generation is greater than the increase in the ratio of water to water. It can be seen that although increasing the feed temperature can increase the water generation ratio, the increase in the heat exchange area leads to an increase in system cost and increases the waste of
prehating heat, so that the system itself can be used to heat the steam and the secondary steam. Water is used as a heat source for preheating of the feed, so that the waste heat can be recovered, and the temperature of the feed after preheating is low, and the influence on the heat exchange area is small.

**Problems in Domestic Multi-effect Evaporation Simulation Design**

Compared with foreign countries, China's multi-effect evaporation technology started late, and the main research results are mainly desalinated, salty wastewater treatment, and pharmaceutical applications, and most of the research still exists in the experimental stage. With the deepening of research, the problems in the application of multi-effect evaporators have become increasingly prominent. The main problems are (1) corrosion problems of evaporation equipment; (2) lack of physical property data of research objects; (3) limitations of software simulation (4) The problem of control manipulation limitations of multi-effect evaporation systems. The research on multi-effect evaporators in China still needs to invest more research energy and overcome a series of application problems [6].

**Conclusion**

In order to save heat exchange area, we need to design as many heat exchange modules as possible, with higher feed temperature and heating temperature. In order to save energy, we need to increase the heat exchange area and try to use the latent heat of evaporation. The corresponding experimental device must be established in the later stage to test to determine the correctness of the results.

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