The Research and Development of Mechanical Vapor Recompression Evaporation Energy-Saving System

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Abstract: In order to solve the problem of high energy consumption for evaporators, the energy-saving evaporation technology of Mechanical Vapor Recompression (MVR) was proposed in this paper. The enthalpy of the thermal steam compressed by the compressor was increased, and the vapor was used to heat the raw material of the evaporator. The fresh steam is saved and the energy consumption was reduced too. And the energy-saving system of mechanical vapor compression evaporation was researched and developed. It is mainly composed of fluid tanks, preheaters, evaporator, separator, vapor compressor and on-line monitoring and controlled system. In addition, the operating costs were compared between MVR system and the traditional there-efficient evaporator. The results show that the economic benefit of MVR system is more remarkable than traditional there-efficient evaporation.

Keywords: Mechanical Vapor Recompression (MVR); multi-effect evaporation; evaporator; energy-saving

1 INTRODUCTION

Evaporation and concentration is very typical chemical operation process. They are widely used in the petroleum, chemical industry, food, drying, etc. The saturated steam is the main heating source of the operation process of evaporation and concentration. When the process load is large and viscosity of the raw material is low, it needs a large of steam. As the rising of steam prices, the operating costs of evaporation are higher and higher. In order to reduce the operating costs, more and more scientific and technical workers pay attention to energy conservation technologies.

At present, the multiple effect evaporation is the main evaporation process. The former effect evaporator produced secondary steam used to heat the raw material of the following effect evaporator. However, as the evaporators increasing, the energy-saving of multi-effect evaporation is not really ideal and single or multiple effect evaporation process must need large amounts of fresh steam. The technology of Mechanical Vapor Recompression (MVR) is proposed, thermal vapor recompress to be used as heating medium for evaporator. It can save energy and improve the economic benefit [1]. Recently, many domestic and foreign scholars and research institutions dedicate to the research of the Mechanical Vapor Recompression. The energy-saving technology of Mechanical Vapor Recompression has been widely used in the chemical industry, foods, papermaking, pharmaceuticals, seawater desalination and wastewater treatment abroad [2-6]. But it is still in the development of exploration stage in domestic. For example, Nanjing University of Aeronautics and Astronautics is carrying out industrial application research of Mechanical Vapor Recompression [7-8]. Therefore, it is necessary to carry out the research and development of MVR system.

2 DEVELOPMENT OF THE MVR SYSTEM

The evaporation process requires a large of fresh steam to be used as heating medium. The Mechanical Vapor Recompression (MVR) system has been developed, its diagram of mechanism and working principle is shown in figure 1. The system mainly contains fluid tanks in the I area, preheaters in the II area, evaporator and separator in the III area, vapor compressor in the IV area and on-line monitoring and controlling system.

The I area in figure 1 contains raw material liquid tank, concentrated liquid tank, condensed liquid tank, fresh steam device. Raw material liquid is stored in the raw material liquid tank. The condensed liquid in production process is sent into the concentrated liquid tank by pump. The concentrated water from the shell of evaporator is sent into the condensed tank. Fresh steam device can supply heating medium at the beginning of the driving or supplement of the heating source. The II area in figure 1 is mainly composed of two plate heat exchangers, they can preheat liquid raw materials. The III area in figure 1 mainly contains evaporator and separator, completing the evaporation and separation of raw material liquid. The IV area in figure 1 includes electric motor, and centrifuged compressor. It can complete the recompression of the thermal vapor used as heating medium for the evaporator.

When MVR system starts, the fresh steam produced by the fresh steam device enters into the shell of evaporator and heats the raw material liquid in the tube of evaporator, the raw material liquid is evaporated to produce thermal steam in the separator, then thermal steam is sent into centrifuged compressor to be compressed and its enthalpy is improved and it is used as heating medium to heat the raw material in the tube of evaporator. The concentrated liquid from the
bottom of the separator is sent into the concentrated liquid tank by pump. In order to make full use of energy, the condensed water from the shell of evaporator is sent into two

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### Table 1: Monitored Parameters, Codes, and Location of the Sensors

<table>
<thead>
<tr>
<th>Number</th>
<th>Monitored Parameters</th>
<th>Codes</th>
<th>Location of Measuring Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>flow of raw material fluid</td>
<td>F1</td>
<td>in inlet pipe of preheater</td>
</tr>
<tr>
<td>2</td>
<td>temperature of raw material fluid</td>
<td>T1</td>
<td>in inlet pipe of preheater</td>
</tr>
<tr>
<td>3</td>
<td>pressure of raw materials fluid</td>
<td>P1</td>
<td>in inlet pipe of preheater</td>
</tr>
<tr>
<td>4</td>
<td>inlet temperature of evaporator</td>
<td>T2</td>
<td>in outlet pipe of evaporator</td>
</tr>
<tr>
<td>5</td>
<td>outlet temperature of evaporator</td>
<td>T3</td>
<td>in outlet pipe of evaporator</td>
</tr>
<tr>
<td>6</td>
<td>flow of the thermal vapor of the separator</td>
<td>F2</td>
<td>in inlet pipe of compressor</td>
</tr>
<tr>
<td>7</td>
<td>inlet and outlet temperature of compressor</td>
<td>T4, T5</td>
<td>in inlet and outlet pipe of compressor</td>
</tr>
<tr>
<td>8</td>
<td>inlet and outlet pressure of compressor</td>
<td>P2, P3</td>
<td>in inlet and outlet of compressor</td>
</tr>
<tr>
<td>9</td>
<td>outlet temperature of condensed water of the shell of evaporator</td>
<td>T6</td>
<td>in outlet pipe of the shell of evaporator</td>
</tr>
<tr>
<td>10</td>
<td>outlet flow of condensed water of the shell of evaporator</td>
<td>F3</td>
<td>in outlet pipe of the shell of evaporator</td>
</tr>
<tr>
<td>11</td>
<td>flow of cycle liquid of separator</td>
<td>F4</td>
<td>in outlet pipe of cycle liquid of separator</td>
</tr>
</tbody>
</table>
plate heat exchangers to be used as heating medium to preheat liquid raw materials, then the condensed water return the condensed tank to be used as the industrial circulating water.

3 ON-LINE MONITORING AND CONTROLLING SYSTEM

3.1 Monitoring Parameters and Location of the Sensor

In order to make the process parameters of the MVR system to be in the optimal operation state, the on-line monitoring and controlling system of parameters was designed. It is an important part of mechanical vapor compression system. The monitored parameters and their codes for on-line monitored and controlling system and location of the sensor are shown in table 1

3.2 The Working Principle of Hardware for Monitoring System

On-line monitoring and controlling system mainly contains sensors of various quarters, signal amplifier, A/D converter data collection card and the terminal computer, etc. Its principle is shown in figure 2.

4 ECONOMIC BENEFIT COMPARISONS BETWEEN MVR SYSTEM AND MUTI-EFFICIENT EVAPORATION

Taking the evaporation of 15ton/h amino acid fermentation liquid for the project example, the operating costs are compared between MVR system and the traditional there-efficient evaporator.

The current market price of electricity is 0.6 Yuan/KWh, and steam is 190 Yuan/ton, and also industrial cooling water is 0.4 Yuan/ton. Working hours are calculated by 24 hours/day, 330 days/year.

(1) Operating Costs for the Traditional There-Efficient Evaporator

Energy consumption ratio for three-effect evaporator is 0.4, the capacity of cooling water is 150m³/h, and the operating costs of the traditional there-efficient evaporator are as follows:

- The cost of the steam consumption:
  \[15 \text{ ton/h} \times 0.4 \times 190 \text{ Yuan/ton} \times 24 \text{ h/d} \times 330 \text{ d} \approx 9 \text{ million Yuan}.

- The cost of cycle water consumption:
  \[150 \text{ m}^3/\text{h} \times 0.4 \text{ Yuan/t} \times 24 \text{ h/d} \times 330 \text{ d} \approx 0.5 \text{ million Yuan}.

(2) The Operating Costs of MVR System

After the design and calculation, the power of Electric motor for MVR system is 310 kW.

The costs of electricity consumption for MVR system are as follows:

- The costs of electricity consumption for MVR system are as follows:
  \[310 \text{ kW} \times 0.6 \text{ Yuan/KWh} \times 24 \text{ h/d} \times 330 \text{ d} \approx 1.5 \text{ million Yuan}.

Then, MVR system can save the operating costs in one year.

\[9 + 0.5 - 1.5 = 8 \text{ million Yuan}.

5 CONCLUSIONS

The mechanical vapor compression evaporation energy-saving system for 15 ton/h of amino acid fermentation liquid was developed. Furthermore, the operating costs analysis and comparison between MVR system and the traditional there-efficient evaporator. The engineering example proved that the economic benefits of MVR system are significant.

REFERENCES


