乙醇超重力 MVR 热泵精馏系统仿真及优化研究

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摘 要 针对超重力 MVR 热泵精馏模拟研究少的现状，对于乙醇–水这一典型非理想物系，基于 Aspen Plus 中重力场精馏塔非平衡级模型，通过编译和调用体积传质和相界面积参数 Fortran 子程序，构建了超重力精馏塔数学模型。在变回流比和进料位置两组工况下，进行了超重力 MVR 热泵精馏系统仿真模拟，将仿真结果与文献中实验结果进行了对比，发现塔顶产品质量分数 x_{D} 的平均误差为 0.74%，系统能效比 COP 的平均误差为 9.52%，单位能耗蒸发量 SMER 的平均误差为 13.26%，表明所建立的仿真模型具有较好的准确性，可用于超重力 MVR 热泵精馏系统仿真。以处理量为 0.3 $\mathrm{m^3/h}$ 的超重力 MVR 热泵精馏系统为例，基于单一变量法，分析了运行参数对系统传质效果和能耗的影响，结果表明系统最佳回流比为 6.8，最佳进料位置为第 15 块塔板，最佳转速为 3000 r/min。

关键词 机械蒸汽再压缩；热泵；超重力精馏；乙醇；仿真
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Simulation and Optimization Study of Ethanol-Water High Gravity MVR Heat Pump Distillation System

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Abstract The thesis focuses on the current situation where there are relatively few simulation studies on the high-gravity MVR heat pump distillation system. For the typical non-ideal system of ethanol-water, based on the non-equilibrium stage model of the gravity field distillation column in the Aspen Plus simulation software, the volume transfer is compiled and transferred. The Fortran subroutine of the parameters of mass and phase boundary area constructs the mathematical model of the supergravity distillation column. Under the two working conditions of changing the reflux ratio and changing the feed position, the simulation of the high-gravity MVR heat pump rectification system is carried out, and the simulation results are compared with the experimental results in the literature. The results show that: The average error for the mass fraction x_{D} is 0.74%, for the system COP is 9.52%, and for the system SMER is 13.26%. This shows that the established simulation model can be used for the simulation of the high-gravity MVR heat pump distillation system. Taking a processing capacity of 0.3 $\mathrm{m^3/h}$ as an example, based on the single variable method, the influence of operating parameters on the mass transfer effect and energy consumption of the system is analyzed. The results show that the optimal reflux ratio of the system is 6.8, the optimal feeding position is the 15th tray, and the optimal rotation speed is 3000 r/min.

Key words MVR; heat pump distillation; high gravity distillation; ethanol; simulation

0 引 言

精馏是化工生产中应用最广泛的分离方法，利用各组分在重力场下的相对挥发度差异实现分离。常规精馏系统中，液体以较厚的流程缓慢流动，气液两相间的传质速率受限，为达到生产目标，精馏塔的高度常在 10 m 以上，体积和占地面积均较大。此外，系统 95% 以上的热能被塔顶冷却水带走，变

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