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Heat Transfer Enhancement and Optimization of Lean/Rich Solvent Cross Exchanger for Amine Scrubbing

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Abstract

The lean/rich amine cross exchanger is one of the cost centers in the amine scrubbing process, and accounts for 20–30% of the capital cost. To minimize the cross exchanger cost, shortcut methods that determine optimum LMTD and fluid velocity were developed. The optimum LMTD is a function of heat transfer coefficient, temperature change and the capital cost of heat exchanger. A greater LMTD should be used to prevent excessive capital cost when the number of heat transfer units (NTU) is large and the heat transfer coefficient is small. The heat transfer performance can be enhanced by increasing pressure drop and reducing solvent viscosity. The corrugation angle is the primary design geometry for plate-and-frame exchanger (PHE). Based on the empirical correlations for PHE, the heat transfer coefficient at 60° is almost double that at 30°; however, the pressure drop at a large corrugation angle is also greater. The dependence of the pressure drop per unit length on the heat transfer coefficient is 0.35–0.40, which implies that the heat transfer coefficient will increase 30% by doubling the pressure drop per unit length. The cost associated with the optimization of the cross exchanger has been developed as a function of the fluid velocity, the physical properties, the exponents of the empirical correlations and the pricing parameters. The optimum velocity is independent of the solvent rate, the temperature change of the cross exchanger, and the cross exchanger LMTD. To stay at optimum fluid velocity, the plate number needs to increase as the solvent rate increases while the plate length will increase as the NTU increases. Viscous solvent will result in a lower optimum velocity since it causes higher pressure drop. Typical optimum fluid velocity is at 0.32–0.42 m/s for 8 m PZ. It is worthwhile to utilize higher fluid velocity and pressure drop when the heat transfer can be effectively enhanced by turbulence.

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1. Introduction

In the amine scrubbing process, the lean/rich amine cross exchanger is used to recover the sensible heat from the hot lean solvent. The cross exchanger heat duty is 3 to 5 times the actual reboiler duty input. Since a large amount of heat is transferred, the capital cost of the cross exchanger is one of the cost centers, accounting for 20–30% of capital cost [1].

To reduce the cross exchanger cost, the most important design parameter, the log mean temperature difference (LMTD), should be optimized. Furthermore, the heat transfer performance can be enhanced by increasing the pressure drop and using a less viscous solvent. This paper aims at investigating the pressure drop and viscosity effect on the cross exchanger performance and reducing the capital cost by providing an optimum design. The plate-and-frame exchanger will be considered to be the type used for the cross exchanger. Mechanical and structure design will not be in the scope of this work.

Nomenclature

A	heat exchanger area
C_{COE}	cost of electricity
C_f	constant in pressure drop correlation
C_{Nu}	constant in heat transfer correlation
C_p	heat capacity
C_{PEC}	purchased equipment cost
D_e	equivalent diameter ($=2\delta$)
f	fanning friction factor
h	heat transfer coefficient
k	thermal conductivity
L_T	total length of flow path
Nu	Nusselt number ($=hD_e/k$)
m	exponent of Re
$\dot{m}$	solvent mass flow rate
n	exponent of Pr
p	exponent in pressure drop correlation
Q	exchanger heat duty
Re	Reynolds number ($=\rho u D_e/\mu$)
T_{stm}	steam temperature
T_{reb}	reboiler temperature
U	overall heat transfer coefficient
$\dot{V}$	solvent volume flow rate
u	fluid velocity
W_p	width of each plate
W_T	total width of plates
Greek	
α	capital cost scaling factor
β	capital cost annualizing factor
ΔP	total pressure drop
$\Delta P/L$	pressure drop per unit length
ΔT_{LM}	log mean temperature difference
δ	plate spacing
η_p	pump efficiency
η_{tb}	steam turbine efficiency