4th Post Combustion Capture Conference (PCCC4)

Effect of liquid viscosity on mass transfer for packings

Di Song[a,b], A. Frank Seibert[b], Gary T. Rochelle[a,*]

[a]McKetta Department of Chemical Engineering, The University of Texas at Austin, 200 E Dean Keeton St., C0400, Austin, TX 78712, USA
[b]Separations Research Program, Pickle Research Center, The University of Texas at Austin, 10100 Burnet Rd., Austin, TX 78758, USA

Keywords: post-combustion amine capture, liquid viscosity, mass transfer area, liquid film mass transfer coefficient, packings

1. Introduction

A good prediction of mass transfer rate in packed columns is crucial for an efficient column design. Liquid viscosity is one of the physical properties that affects gas-liquid mass transfer rate in different separation tasks including post-combustion CO_2 capture with amines. Amine solvents typically have viscosity 5-15 times greater than water. The increased liquid viscosity will impede mass transfer in the absorber and the stripper by slowing diffusion of CO_2 and loaded amine to the bulk liquid, the diffusion of free amine to the liquid-gas interface, and reducing liquid turbulence on the packing surface.

Structured and high performance random packings are commonly used as column internals. The models of gas film mass transfer coefficient models are reasonably consistent, but models of the liquid film mass transfer coefficient (k_L) are not consistent in representing the effect of liquid viscosity. A good prediction of liquid film mass transfer coefficient (k_L) and mass transfer area (a_e) is important for an efficient design of packed columns. Despite the large numbers of existing correlations, most of them only investigated water with little variance of liquid viscosity. Amine scrubbing solutions frequently had higher viscosity than water. Therefore, extrapolation of existing correlations to amine scrubbing is problematic.

This work investigated the effect of liquid viscosity on a_e and k_L by chemical absorption of ambient CO_2 into dilute sodium hydroxide solutions, and air stripping of toluene from water in a semi-works scale (0.43 m I.D.) packed column. The liquid viscosity was varied from 1 to 70 cP by varying the glycerol concentration from 0 to 89 wt %. Packings with variable specific area, corrugation angle, and special corrugation channel design were investigated. A total of nine packings were studied, which include seven structured packings (M 125Y, M 250X, M 250Y, GTO 250Y, GTP 350Y, GTPAK 500Y, and B1 250MN,), one random packing (RSR 1.5), and one hybrid packing (RSP 250Y).

Together with the mass transfer data of another 20 packings in the air-water column database of the Separations Research Program, models of a_e and k_L have been developed.

2. Methods and Equipment

The PVC packed column used in this work is sketched in Fig. 1. The inside diameter of the column was 16.8 in. The maximum packing height was 10 ft. The gas and liquid had countercurrent contact inside the column with air supplied by a 30-kW blower with variable speed drive from a duct (8 in outside diameter) below the packing support. The liquid was discharged by a centrifugal pump regulated with a variable speed drive with a maximum capacity of 150 gpm from a 350-gallon storage tank. The liquid could either flow to the column top and distributed by an F40 distributor (40 drip points/ft^2) or flow back to the column sump and storage tank via a bag filter for the pump to operate at a more favorable drive-speed region. Above the distributor was a Trutna collector to knock out

any liquid reaching the column exhaust. Typical liquid inventory size was 250–300 gallon. Typical gas and liquid rates were 150–750 acfm and 1–30 gpm/ft^2 respectively.

Approximate 10 ft packing was installed for a_e measurement and k_L measurement with aqueous glycerol. A shorter 6 ft bed was used for k_L measurement with water because of the difficulty of GC analysis for the low outlet toluene concentration caused by high mass transfer efficiency. Each element was installed with 90° rotation with adjacent elements to facilitate liquid distribution as a routine practice.

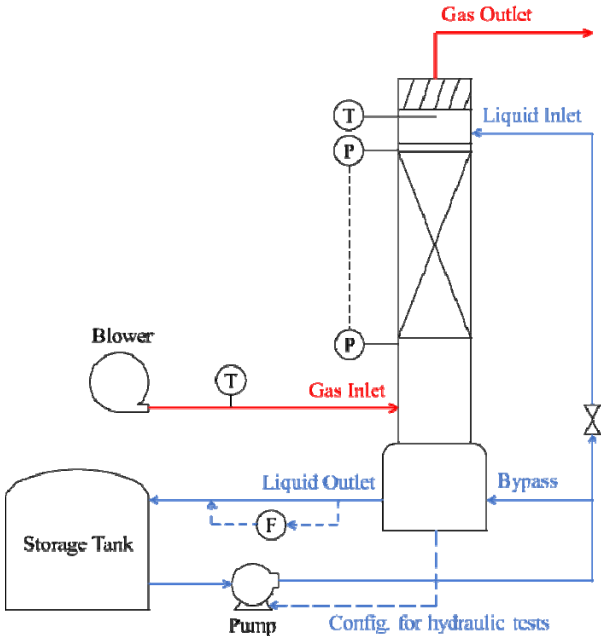

Fig. 1: Packed column experimental system

3. Results

Fig. 2 shows the comparison of calculated a_e from the model and the experimental value. Per the model, surface tension affects a_e but not viscosity.

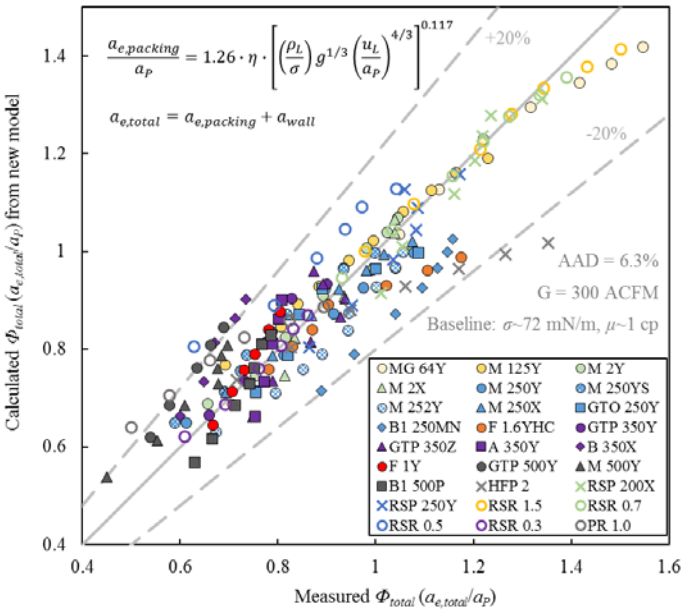

Fig. 2: Comparison of measured and calculated area for water

Fig. 3 shows the comparison of calculated k_L from the model and the experimental value. The total dependence on μ_L of k_L is the same (-0.72) for structured, random, and hybrid packings, which means the impeding effect of μ_L on k_L is the same for all three types of packings. Of the total -0.72 dependence, -0.35 is from the indirect influence of μ_L through diffusivity, and -0.37 is from the direct influence of μ_L on k_L through liquid turbulence. The indirect part is believed to be system dependent, and requires knowledge on the D-μ relationship. The direct part is universally applicable to all Newtonian liquids.

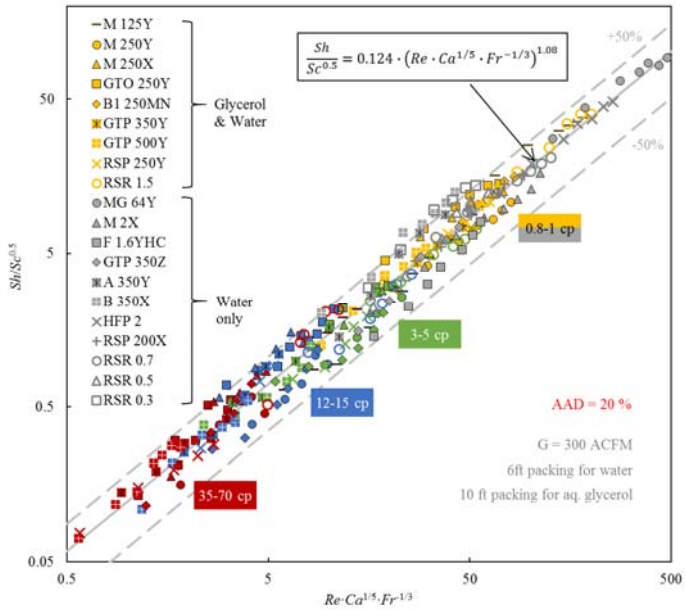

Fig. 3: Comparison of measured and calculated k_L

With a relatively large equipment size and packing database, this work has the greatly expanded the data of mass transfer in viscous liquids available in the open literature.