Effect of liquid viscosity on liquid phase mass transfer coefficient for packings

Di Song

University of Texas at Austin

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μ_L affects k_L in two ways

$$k_L\ (k_L a) = C_1 \cdot \mu^{\alpha} \cdot D^{\beta}$$

$$D = C_2 \cdot \mu^{\gamma}$$

$$k_L\ (k_L a) = C_3 \cdot \mu^{\alpha+\beta\gamma}$$

- α – Direct influence via the turbulence of liquid
- $\beta\gamma$ – Indirect influence via *D* of mass transfer species

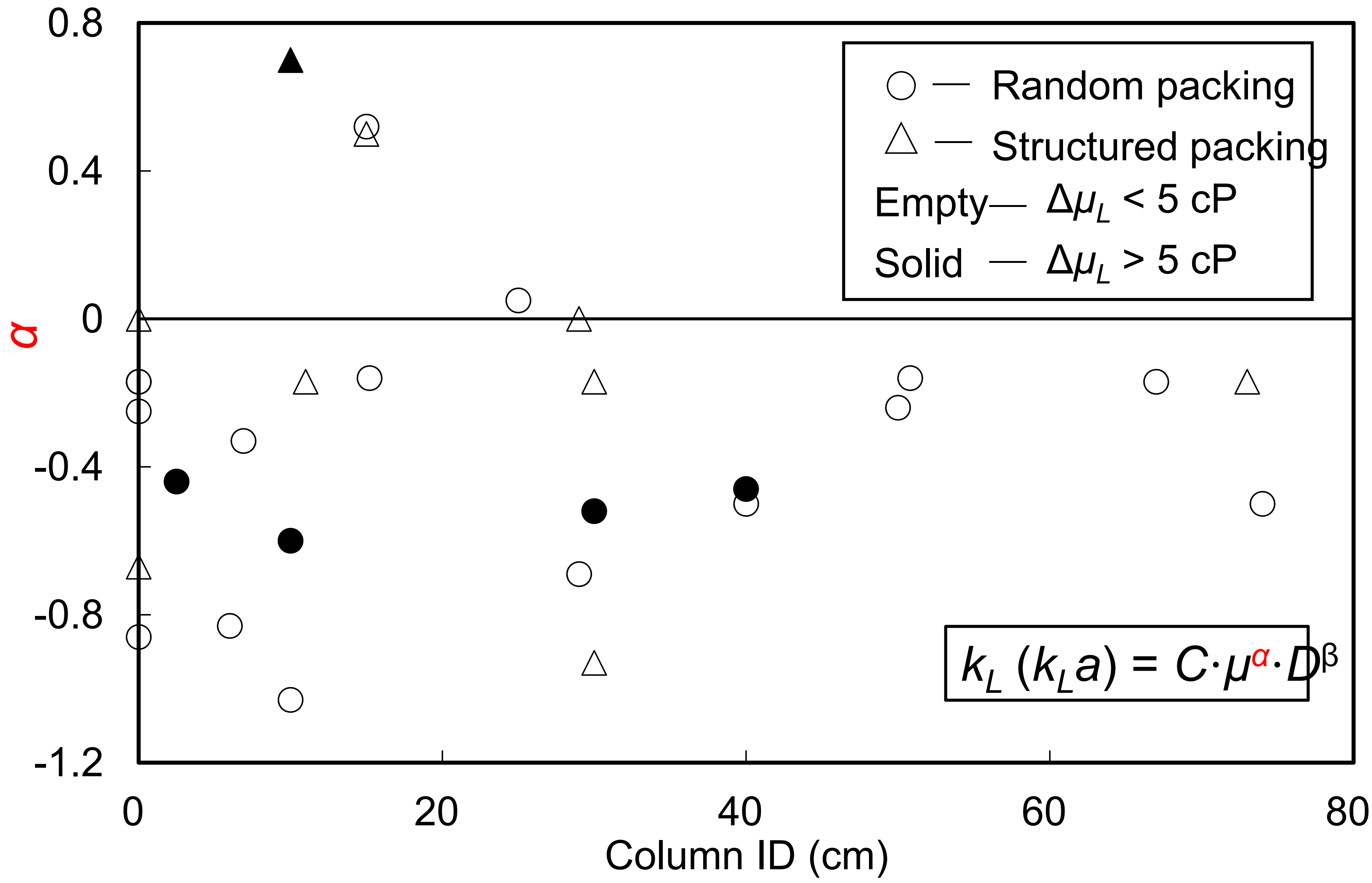
Industrial applications with viscous liquid

- ☐ Electrolyte solutions
- ☐ Organic/polymer solution
- ☐ Crude oil
- ☐ Ionic liquids
- ☐ PCCC

Amine soln. (α = 0.4)	5m PZ	8m PZ	8m MEA	H_2O
μ @ 40 ℃	3.6 cP	11.4 cP	2.4 cP	0.65 cP

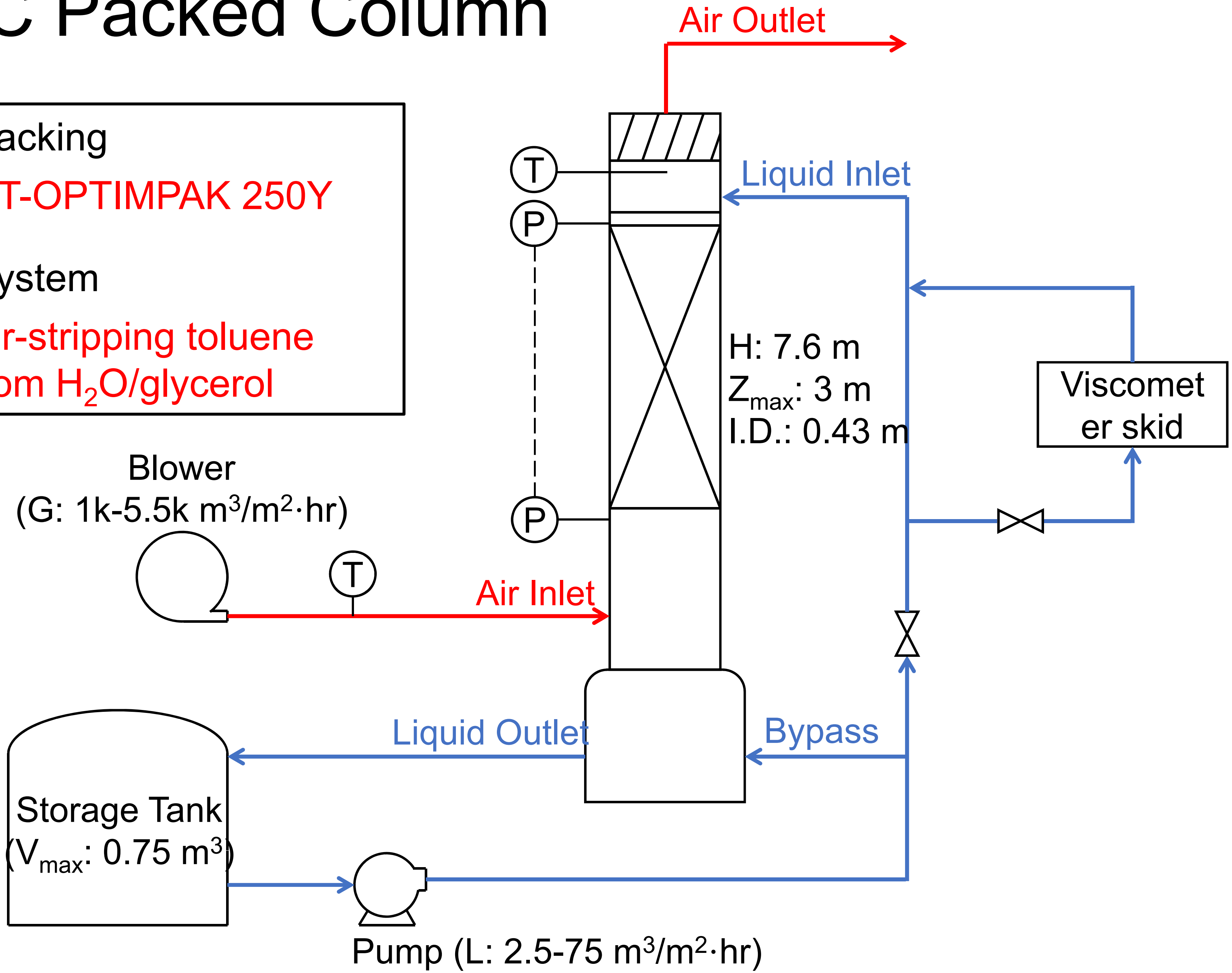
- Slower diffusion of CO_2 to bulk liquid
- Slower diffusion of free amine to L-G interface (surface depletion)
- Slower diffusion of loaded amine back to bulk liquid (P^*_{CO2})
- Less liquid turbulence

Existing k_L models



PVC Packed Column

- Packing
  - GT-OPTIMPAK 250Y
- System
  - Air-stripping toluene from H_2O/glycerol



Viscometer Skid

- **Installation**
  - Liquid inlet
  - Bypass of main streams
- **Design**
  - Online data: μ, ρ, T
  - μ: 0.5-100 cP
  - L: 3-6 gpm
  - Transportable
  - Standalone

k_L Correlations

- $k_L a_e$ from empirical data: $$k_L a_e = \frac{u_L}{Z} \ln\left(\frac{C_{toluene,in}}{C_{toluene,out}}\right)$$

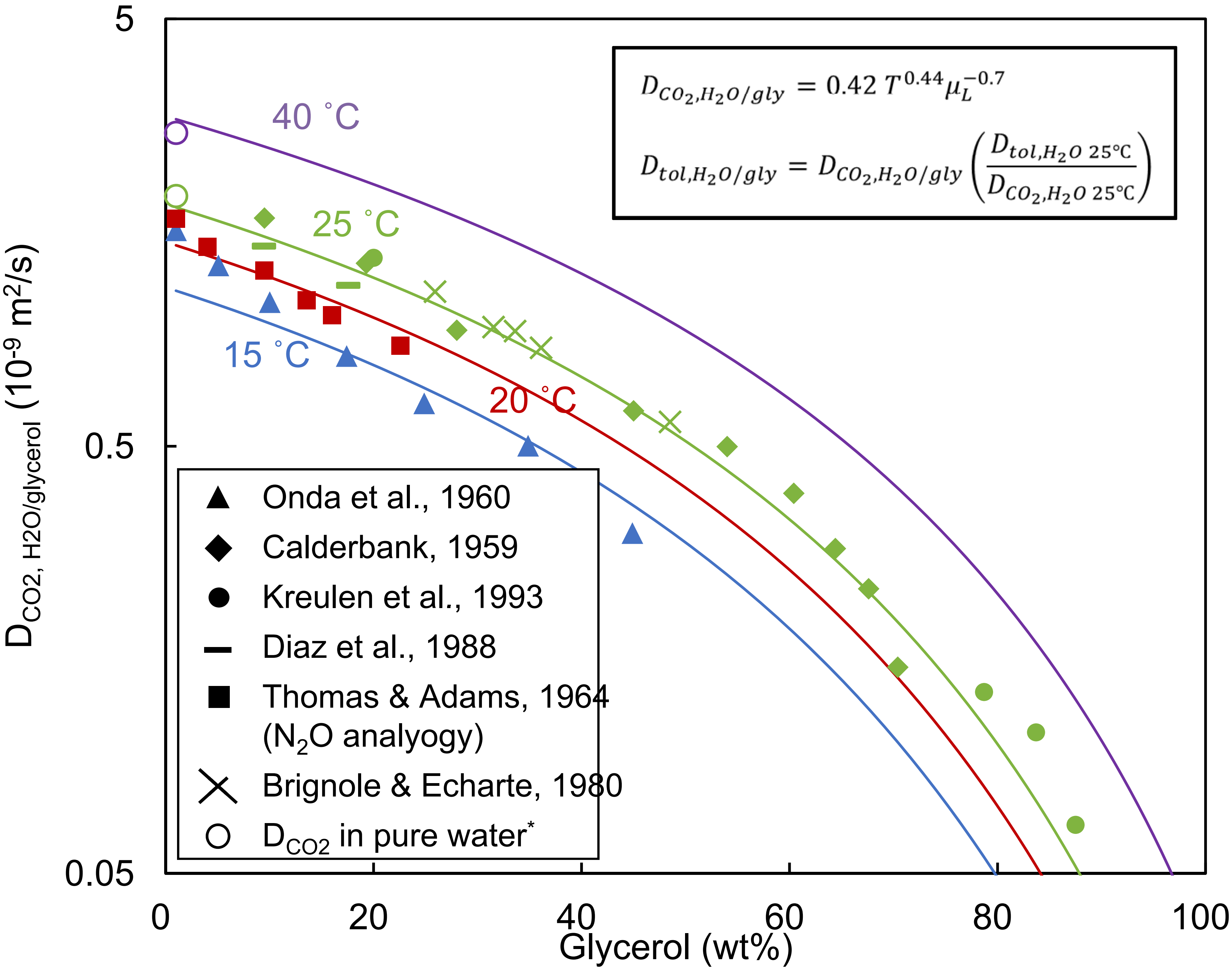
- a_e from Wang, 2015: $$\frac{a_e}{a_P} = 1.41 \left[\left(\frac{\rho_L}{\sigma}\right) g^{1/3} \left(\frac{u_L}{a_P}\right)^{4/3}\right]^{0.116}$$

- k_L from this work: $$k_L = 21.7\, u_L^{0.47}\, D_{tol}^{0.5}\, \mu_L^{-0.37}$$

- D_{tol} in H_2O/glycerol: $$D_{CO_2,H_2O/gly} = 0.42\, T^{0.44} \mu_L^{-0.7}$$ $$D_{tol,H_2O/gly} = D_{CO_2,H_2O/gly} \left(\frac{D_{tol,H_2O\ 25°C}}{D_{CO_2,H_2O\ 25°C}}\right)$$

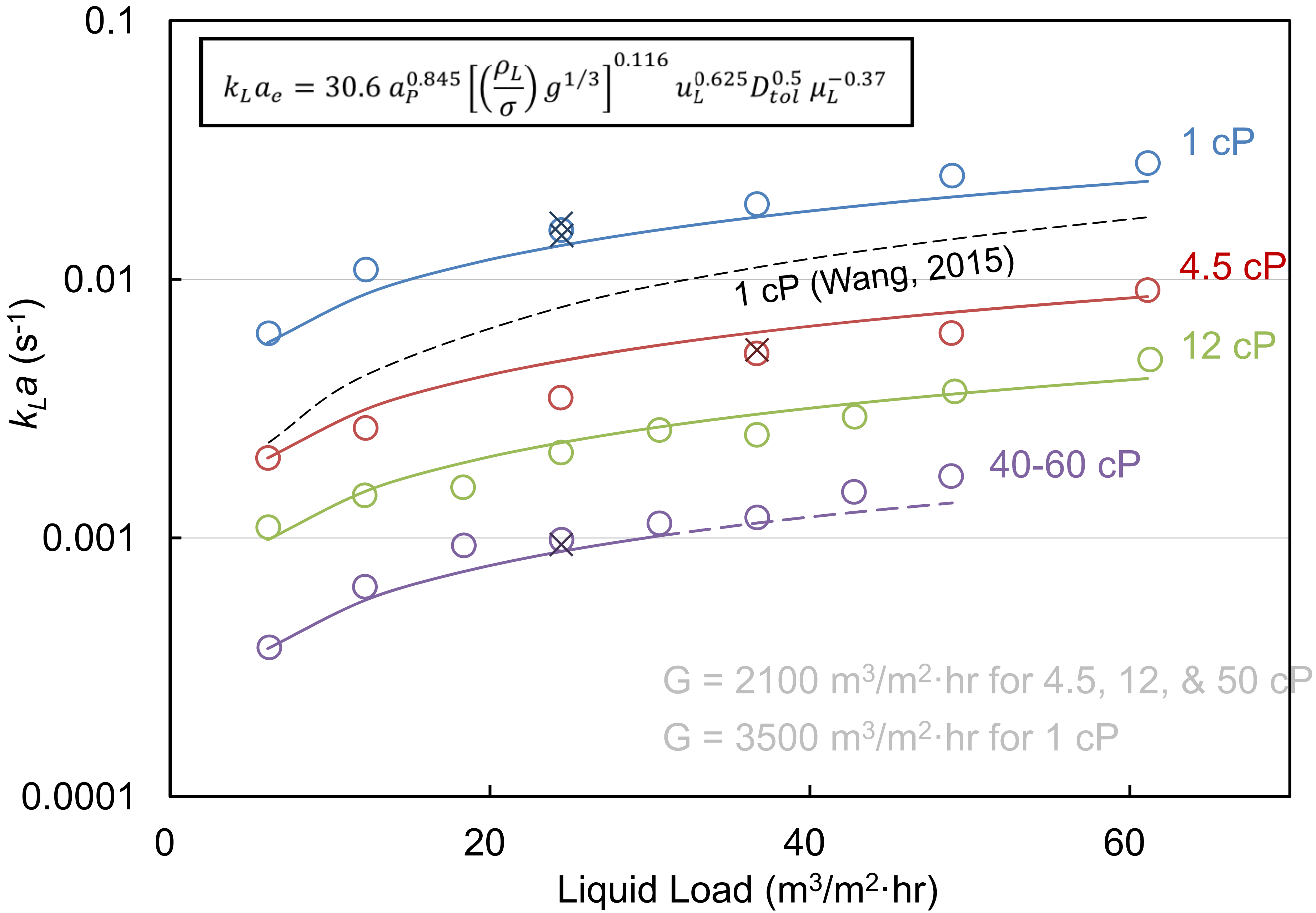
- Combined correlation of $k_L a_e$:

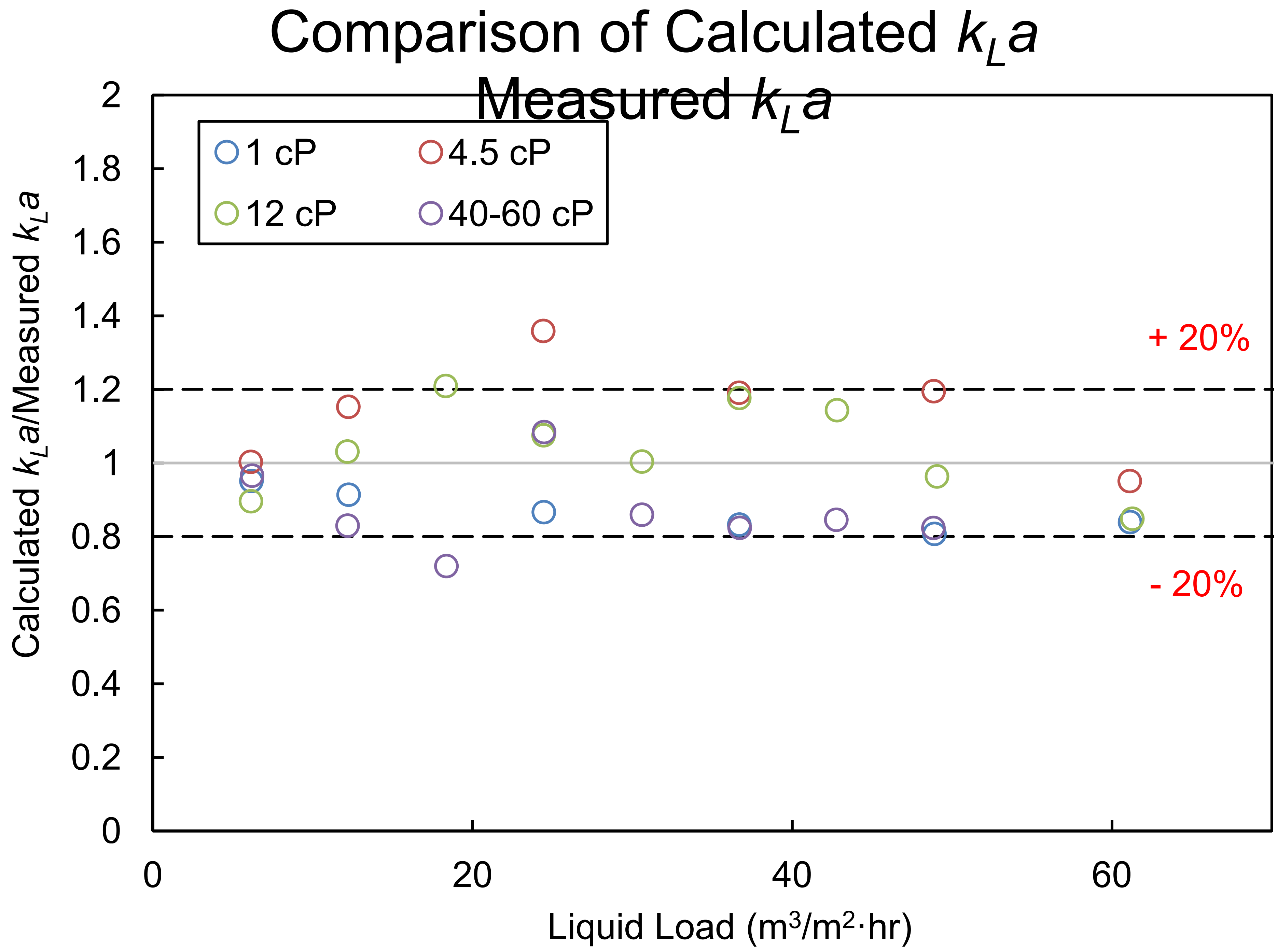
$$k_L a_e = 30.6\, a_P^{0.845} \left[\left(\frac{\rho_L}{\sigma}\right) g^{1/3}\right]^{0.116} u_L^{0.625} D_{tol}^{0.5}\, \mu_L^{-0.37}$$



5
0.5
0.05
0
20
40
60
80
100
Glycerol (wt%)
$D_{CO2,\ H2O/glycerol}$ (10^{-9} m^2/s)
40 °C
25 °C
20 °C
15 °C
$D_{CO_2,H_2O/gly} = 0.42\ T^{0.44} \mu_L^{-0.7}$
$D_{tol,H_2O/gly} = D_{CO_2,H_2O/gly} \left(\frac{D_{tol,H_2O\ 25°C}}{D_{CO_2,H_2O\ 25°C}} \right)$
Onda et al., 1960
Calderbank, 1959
Kreulen et al., 1993
Diaz et al., 1988
Thomas & Adams, 1964
(N_2O analyogy)
Brignole & Echarte, 1980
D_{CO2} in pure water*

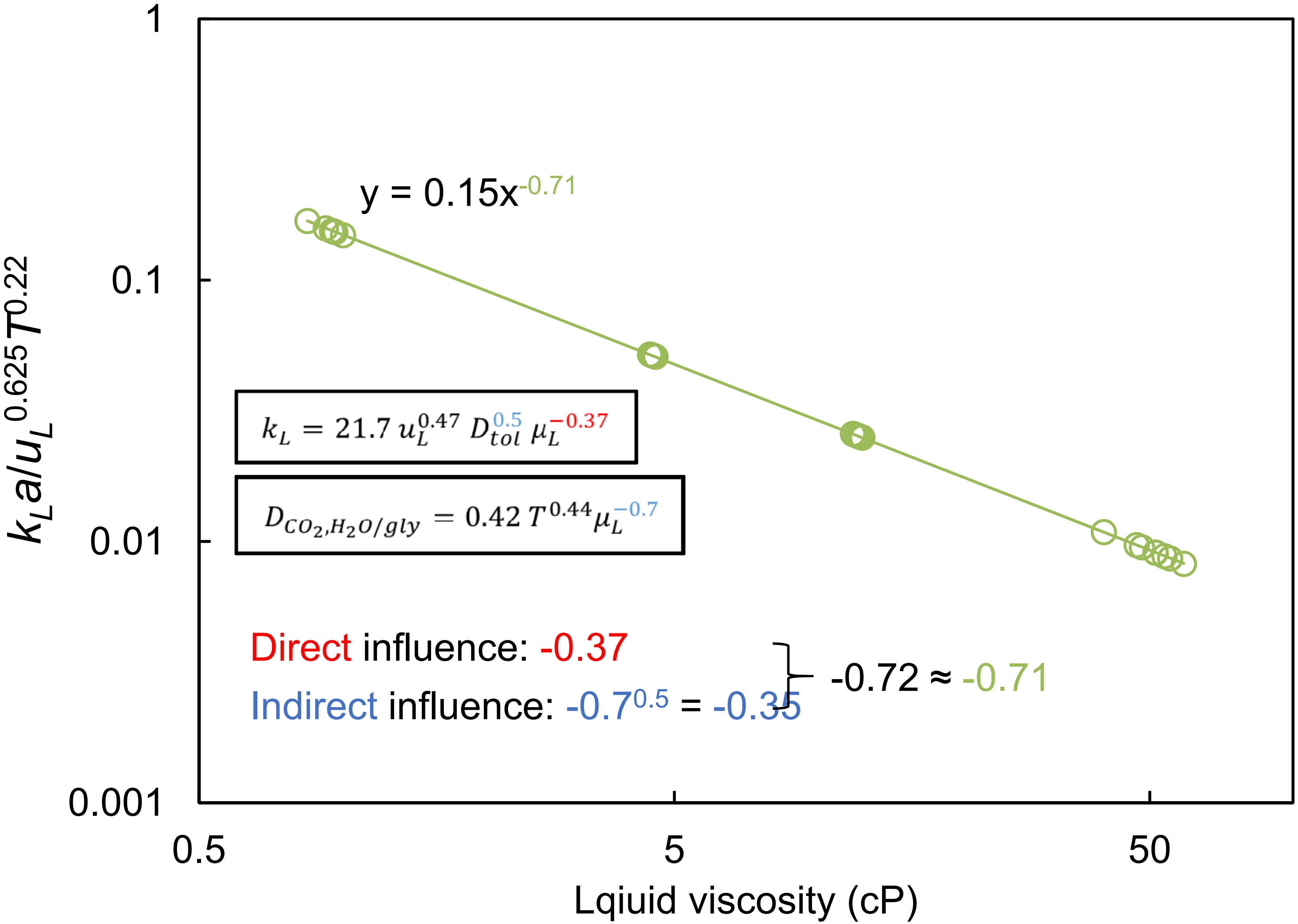
Raw data & correlation of $k_L a$



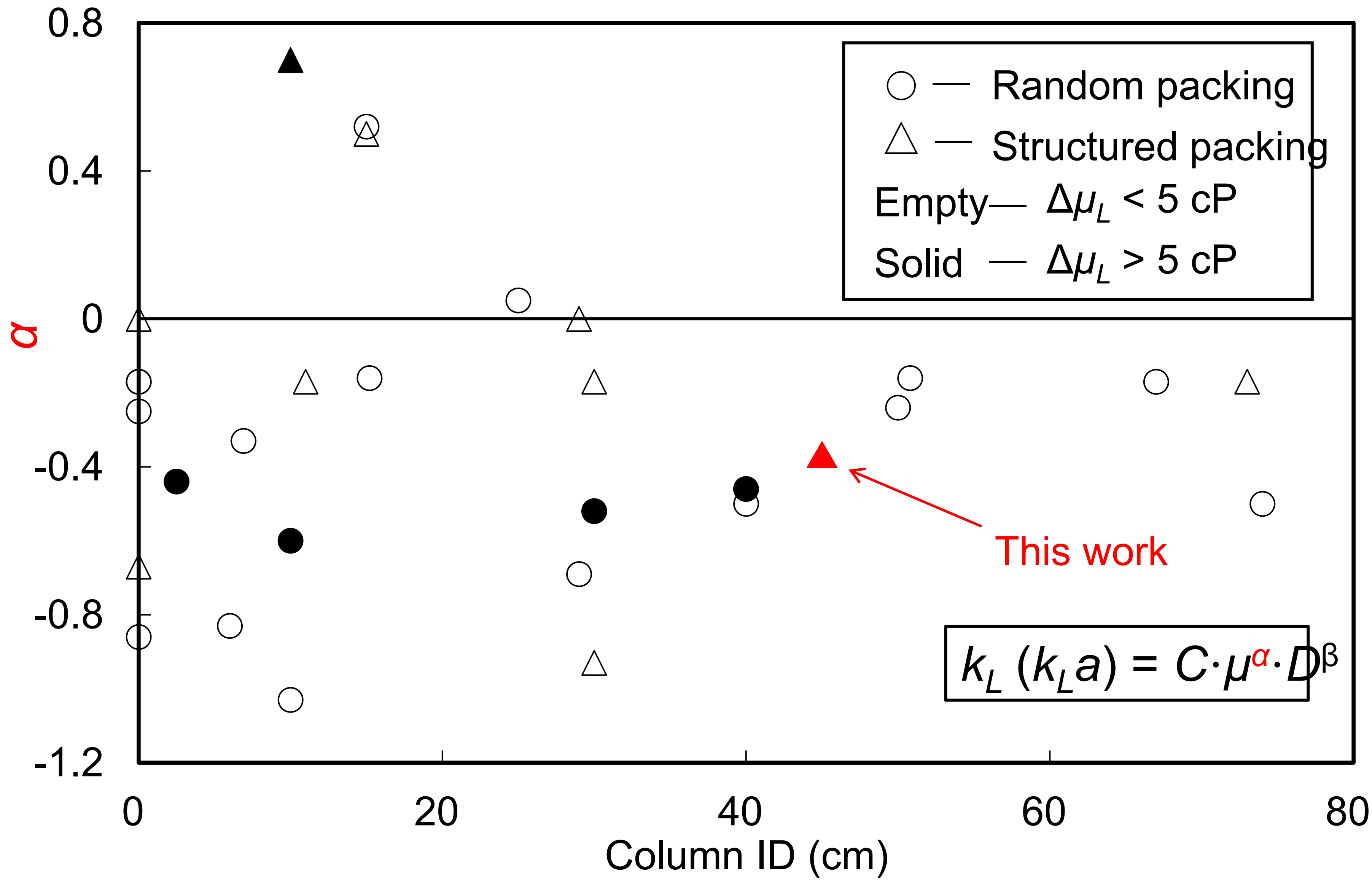


Comparison of Calculated k_La Measured k_La
1 cP
4.5 cP
12 cP
40-60 cP
+ 20%
- 20%
Calculated k_La/Measured k_La
Liquid Load ($m^3/m^2 \cdot hr$)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
20
40
60

Depdence of $k_L a$ on liquid viscosity



Existing k_L models



Conclusions & Future Work

Conclusions

- For air stripping of toluene from water/glycerol using GT-OPTIMPAK 250Y, total dependence on μ_L of k_L is -0.72, in which direct/indirect dependence has about the same effect.

Future Work

- a_e measurement using CO_2/NaOH/H_2O/glycerol for GT-OPTIMPAK 250Y
- k_L measurement for MP250Y & RSP250Y (and more)

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Thank you!

Di Song
dsong@utexas.edu