Liquid Hold-up and Pressure Drop in Mellapak 2X

Ali Zakeri
Aslak Einbu
Lars E. Øi
Hallvard F. Svendsen

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Packed Columns:

- Packed towers and tower packings have been in use for more than 100 years. Some early examples of their application involve the production of sulfuric acid and the purification of coke oven gas. Prior to 1915, these towers were filled with coke, random-sized and -shaped quartz, broken glass, or broken crockery.

- Tower performance was unpredictable and no two towers would perform alike. The development in 1915 of the Raschig rings made it possible for the first time to impart a degree of predictability and dependability to tower performance.
Structured Packing

- The use of structured column packing dates back to the 1960s. The packings are generally manufactured from different materials such as ceramics, metal and plastics and divided according to their shape into: gauze packing, grid type packings, metal sheet and random packings.

- Mellapak is the most widely used structured packing worldwide. It has proven excellent performance in columns with diameters up to 15 m. It is supplied in sheet metal thicknesses from 0.1 mm up.

**Special features**
- Pressure drop per theoretical stage 0.3-1.0 mbar
- Pressure drop at 70-80% flooding about 2 mbar/m
- Minimum liquid load approx. 0.2 m³/m²h
- Maximum liquid load up to more than 200 m³/m²h
Hydrodynamics in packed beds

- The liquid hold up is an important hydrodynamic parameter for gas liquid flow in packed beds. It enables the determination of the pressure drop and the fluid effective velocity within the packing. The latter is further used for determination of the liquid side mass transfer coefficient, the liquid hold up is also used to design support devices for the column since it gives the liquid weight in operation.

- Pressure drop in packed columns is an important parameter especially in atmospheric and vacuum columns where the separated liquid is sensitive to temperature.
Liquid Hold-up in packed bed

There are two different types of liquid holdup in a packed bed:

- **static**:
  
  Static holdup represents the volume of liquid per volume of packing that remains in the bed after the gas and liquid flows are stopped and the bed has drained.

- **operating**:
  
  Operating, or dynamic, holdup is the volume of liquid per volume of packing that drains out of the bed after the gas and liquid flows to the column are stopped.
The static holdup is dependent on:

- the packing surface area
- the roughness of the packing surface
- the contact angle between the packing surface and the liquid
- System properties

Operating holdup primarily is a function of the liquid flow rate and gas/liquid system properties.
The VOCC test rig
The VOCC project

To experimentally characterize various packing materials under varying conditions of gas and liquid flow and chemical system properties

Map the interaction between absorbent and packing properties

To study the effects of exhaust gas with CO$_2$-content between 3-14 vol% on the performance of the absorber

To use the experimental data for validation of in-house software as a basis for absorber and desorber design
The VOCC test rig

- 5 m packing (different packings will be tested)
  ID 500 mm column
  Max gas velocity 5 m/s
  Liquid flow up to 10,000 l/h

- Pressure and temperature measurement every meter

- Section below packing for measuring liquid distribution

- Setup for liquid hold-up measurements

- 300 kg CO$_2$ per hour max capacity

- 2 x 2000 liter amine tanks for batch operation

- Well instrumented desorber rig (not shown) for regeneration of rich amine (52 kW electric reboiler)
Experimental results on relationship between liquid holdup, the phase loads in the packed column (Air/Water – 1 cP).
Experimental results on relationship between liquid holdup, the phase loads in the packed column (Air/Water-Sugar – 3 cP).
Experimental results on relationship between liquid holdup, the phase loads in the packed column (Air/Water-Sugar – 6 cP).
Comparison with SULCOL
Air- Water 1cP

![Comparison Graph]

- **Superficial gas velocity (m/s)**: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0
- **Holdup (%)**: 2.0, 7.0, 12.0, 17.0, 22.0

- **13.5 lit/min 1-cP**: Blue line
- **153 lit/min 1-cP**: Cyan line
- **153 lit/min 1-cP - SULCOL**: Green line
- **13.5 lit/min 1-cP - SULCOL**: Purple line
Comparison with SULCOL
Air-Water/Sugar 3cP

Air-Water-Sugar 3-cp

- 153 liters/min
- 153 liters/min SULCOL
- 13.8 liters/min
- 13.8 liters/min SULCOL

Superficial gas velocity (m/s) vs. Holdup (%) graph.
Comparison with SULCOL
Air-Water/Sugar 6cP

Superficial gas velocity (m/s)

Holdup (%)

Air-Water-Sugar 6-cp

Comparison with SULCOL
Air-Water/Sugar 6cP
DISCUSSION
Experimental curves for the total hold-up $h_L$ in a Mellapak 2X packing at various air and water loads were measured. Two regions can be distinguished:

- **A low gas-load region** in which the hold-up $h_L$ depends solely on the liquid load, the linear part of the curves.

- **A high gas-load region** in which $h_L$ depends on both the liquid load and the vapor loads, the curvy part of the curves.

The transition between these two regions occurs at the loading point.
DISCUSSION

• Hold-up increases with increased viscosity. The influence of viscosity is stronger at high liquid load than at low liquid load. Alix and Raynal (2008) indicate a power law dependency of 0.13 in experiments with Mellapak 252Y. We found a higher dependency at high liquid load and a lower at low liquid load.

• In the correlations of Rocha et al. (1993), the liquid hold-up is an important parameter in pressure drop estimation. The liquid hold-up and then the pressure drop is expected to increase with increasing liquid viscosity.

• Our experimental hold-up results are significantly higher than what can be predicted from SULCOL. This discrepancy is under investigation
The dry pressure drop is measured in packed column in absence of liquid flow. Good agreement between our experimental data and predictions from SULCOL.
Pressure drop was measured based on pressure measurement at 6 positions along the packing height. The liquid flow rate was between 0 and 55 m³/(m²·h), and gas flow was between 0 and 17000 m³/(m²·h). The pressure profiles through the packing were close to linear.
Pressure Drop in M2X Water/Air-1cP

![Graph showing the relationship between Fv/(m/s)(Kg/m3)^0.5 and Pressure Drop (mbar/m).]

Pressure Drop (mbar/m)

Fv/(m/s)(Kg/m3)^0.5

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Pressure Drop in M2X Water/Air-Sugar-3cP

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Pressure Drop in M2X Water/Air-Sugar-6cP

![Graph showing pressure drop vs. Fv (m/s)(Kg/m3)^0.5 with specific data points:]

- 53.6 m³/m²h
- 31.8 m³/m²h
- 13.9 m³/m²h
- 2.7 m³/m²h

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Air Water- 1 cP

Air-Water 1-cP

Pressure Drop (mbar/m)

Fv(m/s)(Kg/m^3)^0.5

153 lit/min 1-cP

13.5 lit/min 1-cP

13.5 lit/min 1-cP SuLCOL
Air- Water-Sugar 3-cP

![Graph showing pressure drop vs. Fv(m/s)(Kg/m3)^.5 for different flow rates of Air, Water, and Sugar 3-cP with labels for 13.8 lit/min - 3 cp and 166.8 lit/min - 3 cp SULCOL.]
Air-Water- Sugar 6 cP

Pressure Drop (mbar/m) vs. $F_v (m/s)(Kg/m^3)^{0.5}$

- 13.4 lit/min 6 cp SULCOL
- 152 lit/min 6 cp
- 13.4 lit/min 6 cp SULCOL
DISCUSSION

- The pressure drop values in the figures are based on the pressure instruments just below and just above the packing. The total pressure drop followed the expected pattern as a function of liquid and gas flows.

- The column showed flooding-like behaviour at superficial gas velocities of about 3 - 4 m/s depending on the liquid flow. (The flow factor is about 1.1 times the gas velocity at the given conditions.)

- The pressure drop increases slightly with increased viscosity. According to traditional flooding and pressure drop charts (Strigle, 1993), the pressure drop dependence on liquid viscosity can be seen from the capacity factor, which is proportional to the gas flow in exponent 2 and the liquid viscosity in exponent 0.1 (assuming constant liquid density).
Thank you

Absorber

Desorber