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Comparative Analysis of Packed and Plate Columns

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Abstract: Performance characteristics of gas-liquid contacting devices for mass transfer operations in packed and plate columns have been discussed via theoretical considerations. A comparative analysis was made of sieve plate, random packing and regular packing for the purpose of selecting packed column or plate column for optimal separation processes.

Key words: Comparative analysis, PC, PLC, gas-liquid, devices

INTRODUCTION

Selection of optimal mass transfer equipment is a critical problem in the design, development and modernisation of new and existing gas-liquid contacting devices for mass transfer processes. Many unit operations such as distillation, absorption, desorption, humidification, etc., are carried out in column vessels with packed or plate contacting devices.

The hydrodynamics of Packed Columns (PC) with Random Packing (RAP) is characterized by disorderly movement of flows over time and in cross-sections over the height of the column and longitudinal displacement, as well as channelling. Owing to these indicated characteristic features of a PC, its operating efficiency decreases with increasing diameter.

In a PC filled with Regular Packing (REP), the flow of liquid through the REP is predominantly film in nature and the movement of both liquid and gas flows is orderly over the height of the column and in the cross-section as well. Thus, providing uniform flow in the packed layers. In PC with REP, channelling is eliminated or minimised by creating discontinuities in the liquid film, use of self-wetting packing material, preflooding the tower before operation and use of liquid redistributors at the joints between packing bundles (Peters and Timmerhaus, 1981). PC with REP have low hydraulic resistance and very good mass transfer characteristics.

The movement of flows in a Plate Column (PLC) is well ordered both within the limits of a single plate and on the plates over the height of column. Since by-passing, longitudinal displacement and channelling do not occur on the plates, the stage efficiency per unit height of the effective zone of the vessel in PLC is higher than in PC (Peters and Timmerhaus, 1981; Kagan *et al*., 2005) and is less dependent on scale factor because sectioned plates are normally used in large-diameter columns. For uniform distribution of flows, PLC ensures a scale-transition factor close to unity with increasing diameter (Kagan *et al*., 2005).

A comparative analysis of PC and PLC indicated the following characteristics:

- Compared with PLC, PC has a low hydraulic resistance per height of transfer unit, since the plates operate in a submerged regime and the gas passing through the column must overcome a resistance equal to the total pressure of the liquid column on all plates. According to McCabe *et al*. (2001) the hydraulic resistance of PLC and PC with REP differ significantly. The low resistance of the REP ensures conditions for vacuum distillation in PC while PLC cannot be used for the separation of thermally stable substances. Owing to the thermal resistance of PC with REP, a lower energy consumption is required for its operation (Sinnott, 2004) other conditions being equal.
- PC with both REP and RAP can be operated under heavier gas and liquid loads, as compared with PLC. In PLC, the velocity of the gas does not exceed 0.3-0.6 m s^{-1} due to interplate entrainment, which at high gas velocities lowers the separation efficiency (Gel Prin, 1947, 1981; Aleksandrov, 1978). Limitation of liquid loads in PLC is dictated by the carrying capacity of the overflows and the velocity of the liquid which should not exceed values at which entrainment of gas begins (Ramm, 1976). Increasing the area of the overflow will lead to increase in the liquid load reduction in the effective area of the plates and consequently the carrying capacity with respect to the gas. In PC, the gas velocities may reach 2-2.6 m s^{-1} under atmospheric pressure, while

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Table 1: Characteristic performance features of sieve plate, RAP and REP

Type of contact device	Characteristic features	Hydraulic resistance	Number of theoretical plates
Sieve plate	Area of effective section-1.33 m^2 Area of relative free section-10% Opening diameter-4 mm Discharge perimeter-1.1 m Height of discharge portion-30 mm Distance between plates-400 mm	250	3
RAP	Dimensions-50×50×0.8 mm Filled mass-377 kg m^{-3} Specific surface-101 m^2 m^{-3} Equivalent diameter-34.4 mm Porosity-0.96m^3 m^{-3}	50	1 m
REP	Bundle diameter-245×245×210 mm Slope of corrugations to horizon-45° Specific surface-250 m^2 m^{-3} Equivalent diameter-9.4 mm Porosity-0.96 m^3 m^{-3}	4.8	0.97 m

Source: (Kagan *et al.*, 1992, 2005; Ramm, 1976; Dmitrieva *et al.*, 2005)

in PC with REP, they may attain 3-3.5 m s^{-1} (Treybal, 1981; Dmitrieva *et al.*, 2005) and the reflux density is 150 m^3 $m^{-2}h$ (higher when these and other packings are used). Thus, permitting a considerable reduction in the diameter of PC as compared with PLC.

- PLCs are insensitive to misalignments, which necessitates stringent requirements for their positioning and are less sensitive to contaminants that clog the openings to the plates; unlike the PLCs.
- In contrast to PLC, PC with RAP has a less complex design and lower metal consumption and are less expensive to construct.

In recent years, PCs with REP have been introduced all the more increasingly in process industries requiring heavy gas and light liquid loads (Dmitrieva *et al.*, 2005). However, the high cost of REP is limiting their broad scale use.

Typical experimental literature results of three alternate schemes of unit operations (sieve plate, RAP, REP) for the production of weak nitric acid (Olevskii, 1985) have been presented in Table 1 for maximum air load.

The results of Table 1 indicate that the REP and RAP have advantages over the sieve plate since their use does not increase the height of the column and appreciably lower energy requirement while maintaining the mass-transfer efficiency. The REP is distinguished by the lowest resistance, thus ensuring effective operation of the PC at the high gas flow rates.

CONCLUSION

The comparison of advantages of one contact device over the other is for the purpose of selecting the optimal one. Between the two contact devices studied, PC fitted with REP is recommended for optimal mass transfer operation. However, a decision concerning the use of a different design can also be made with consideration of their market cost.

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