SECTIONALIZING OF STREAMS OF REACTING PHASES IN COLUMN REACTORS IN THE TREATMENT OF SOLIDS WITH A LIQUID (A DISCUSSION)

A. A. Bulanov

UDC 66.023.23:66.048

Sectionalized column reactors are being widely used in chemical technology in the reaction of two- and three-phase systems (gas—liquid—solid). In order to create favorable hydrodynamic conditions and to increase the interfacial contact area, the vertical stream is divided into individual sections by some mass-exchange devices, which reduce considerably the longitudinal mixing, besides progressive technological methods of effective stream distribution (such as vibrating and pulsating interactions, the use of fluidized beds of particles of the dispersed material, the conversion of a gas—liquid system to a mobile unstable foam, etc.).

The development and improvement of sectionalizing devices for the formation of a developed three-dimensional structure of the streams of the reacting phases is necessary in order to improve the mass-exchange effectiveness of the column reactor and thus to improve the technical and economical parameters in the processing of natural raw materials and synthetic intermediate products.

Let us discuss the principles of sectionalization and the design of plates, which provide an intensive interaction of solids with a liquid. In the sectionalization of vertical streams it must diverge from the reactor axis in order to increase the duration of the contact between the phases, to reduce longitudinal mixing, and to increase the homogeneity of the interacting dispersed phase.

In the treatment of slurries and suspensions in column reactors, the constructions of the sectionalizing baffles have some characteristic features, related to the action of the gravitation force fields of mono- and polydispersed particles. In particular, overflow devices cannot be used, the stream of solid material on the plate cannot be recirculated, repeller-separators cannot be applied, etc.).

For the sectionalizing of streams in column reactors it is expedient to use, for the countercurrent interaction of solid materials with a liquid, the following types of plates: perforated plates with deflecting elements; sheet-like, coneshaped, and inclined sieve plates; plates with movable elements; mobile and combined plates.

The use of mass-exchange horizontal baffles of the first type is effective only for low-frequency (pulsating) mixing, the discrete extrusion of the solid material, or the supply of the liquid (reagent) to the lower part of the column reactor. This is due to the need for the traveling of relatively large or high-density solid particles on the surface of the plate toward the openings. Devices of this kind include KRIMZ [1] and GIAP [2] packings, Kittel plates [3-5] without central or peripheral overflow pockets, vortex-forming plates [6] (Fig. 1), sectionalizing baffles with triangular openings [7] and tapered openings [8], discs with openings, the edges of which have arched deflectors [9], and some others.

The breaking up of the flow into streams in plates of this type increases the specific contact area between the phases and improves the homogeneity of the dispersed system.

The contacting devices of the second type are relatively simple to manufacture and can be used for the treatment of large solid particles. In order to reduce longitudinal mixing, plates inclined in different directions must be used in the sections. These include tray-shaped plates [10], laminar devices [11-17] in the shape of inclined solid and/or perforated plates (Fig. 2), inclined plates with horizontal sections, inclined baffles with an aerodynamic profile, etc. Plates with hinged sheets with L-, V-, or Z-shaped cross sections [18]

Translated from Khimicheskoe i Neftyanoe Mashinostroenie, No. 6, pp. 7-9, June, 1993.

0009-2355/93/0506-0260$12.50

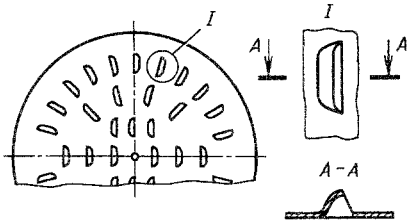

Fig. 1

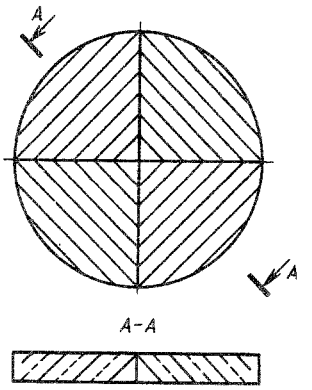

Fig. 2

Fig. 1. Vortex-forming contact plate [6].

Fig. 2. Contact plate made of inclined sheets [12].

are also known. On the surface of such mass-exchange devices the flow is divided into layers of different thickness and deviates from the vertical direction of flow by an angle which is equal to the angle of inclination of the plates.

Contact devices with radial inclined sheets, fixed in the interannular space at an angle which is opposite to the inclination angle of the sheets in the adjacent interannular space, can also be aplied expediently to the system liquid—solid [19]. However, plates with radial inclined blades of the same width (height) suffer from an essential shortcoming: the different distance between the blades in the central and peripheral sections of the interannular space, which leads to an increased longitudinal mixing of the phases.

Column reactors with sectionalized baffles in the shape of inverted truncated cones with deflectors have come recently into widespread use [20-22]. The angle of inclination of the conical plates is chosen by taking into account the possible sliding of the precipitate into the lower sections. In such column reactors a periodical narrowing and widening of the streams takes place, which assists the displacement of valuable soluble substances from the moisture of the precipitates.

The perforated conical plates [23] are of interest. The inclined sieve plates can also be included in this class of mass-exchange contact devices. They can consist of inclined plates with displaced openings for the passage of one of the phases (Fig. 3) [24], of inclined discs with bent-back peripheral edges and openings with a diameter which increases or decreases from the center to the periphery of the reactor [25].

Contact devices with movable elements offer a higher effectiveness, due to a larger contact area between the phases [26]. However, the possibility of using only loose and perforated mobile elements and the difficulty in coordinating the movement of the mobile element and of the dispersed phase in pulsating mixing limits their application to the processing of slurries and suspensions.

Column reactors with a mobile packing installed between immobile grids are not being used sufficiently in mass-exchange processes in the liquid—solid system, although the simplicity of manufacture and the possibility of using different materials (foam polypropylene, polyurethane, etc.) for the manufacture of different shapes of packings (solid or hollow spheres, cubes, hemispheres [27], etc.) offer real conditions for their widespread use; this is particularly important for the treatment of aggressive media and abrasive mineral particles.

The use of perforated plates, fixed on a rod and subjected to mechanical oscillations, is promising. Prochazka's plate [28] can be mentioned among the sectionalizing baffles of this type. A particular characteristic of such devices is the absence of deflecting elements, since already the simplest twin sieve plates can, in the event of variations, sharply reduce the unwanted effect of longitudinal mixing and improve the effectiveness of mass exchange.

From the viewpoint of the optimum organization of the stream structure for the effective performance of mass-exchange processes, the combined plates, the design peculiarities of

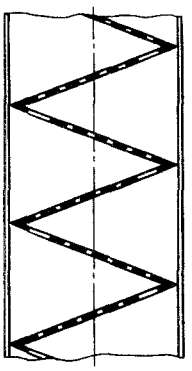

Fig. 3. Contact device consisting of inclined plates with displaced openings [24].

which make it possible to redistribute the flow of the reacting phases in the space between the plates by creating a different hydraulic resistance at some sections of the sectionalizing baffle. A significant transverse phase-mixing effect is observed when the dispersed phase is a finely dispersed material or a product, the density of which is close to the density of the liquid phase. A redistribution of the streams of the reacting phases, which increases transverse mixing, takes place when the contact plates are manufactured with openings, the number of which in the peripheral zone is higher than in the central zone [29] and vice versa (the assembly of such devices into packets must provide for alternation in pairs). A redistribution of the streams takes place when using plates, representing inclined sheets of different heights, increasing or decreasing alternately from the center to the periphery [30], etc. The multifunctional character of the combined plates must be pointed out. They are capable of changing smoothly the hydraulic resistance over the height of the column [21], combining the functions of perforated discs with deflecting elements, of plane and conical plates [31, 32], and improving the effectiveness of mass exchange in the liquid—solid system.

In column reactors, in the case of a descending flow of the dispersed (solid) phase and ascending flow of the continuous (liquid) phase it is recommended to apply longitudinal-transverse sectionalization. This approach has been used in particular in the design of some gas—liquid reactors [33]. With the aim of reducing the metal requirement of the construction, the longitudinal baffles can be manufactured from lighter and cheaper polymeric materials.

The ever-increasing use of columns for the treatment of liquid—solid systems requires a thorough study of the tendencies and development of the design of sectionalized reactors, as well as the improvement and investigation of the technological methods, used in the working volume of the reactor (fluidized beds, pulsating mixing, etc.).

LITERATURE CITED

1. "Packing for pulsating extraction columns," USSR Inventor's Certificate No. 175,489, IPC B 01 D 53/20.
2. "Packing for pulsating and vibration mass-exchange reactors," USSR Inventor's Certificate No. 295,314, IPC B 01 D 53/20.
3. "Plate for column reactors," Patent Switzerland 280,821, IPC B 01 D 3/22.
4. "Contact plate for columns," Patent USA 3,045,989, IPC B 01 D 47/00.
5. "Column plate," Patent FRG 1,071,051, IPC B 01 D 3/22.
6. "Contact plate," USSR Inventor's Certificate No. 540,643, IPC B 01 D 3/18.
7. "Perforated column plate," Patent Rumania 92,589, IPC B 01 D 3/22.
8. "Plate for the contacting of liquids and gases," Patent USA 3,463,464, IPC B 01 D 3/24.
9. "Contact plate for mass-exchange column," Patent France 2,334,394, IPC B 01 D 3/18.
10. "Multiple-hearth plate," Patent Poland 65,259, IPC B 01 D 3/22.
11. "Direct-flow contact plate for the reaction of a liquid with a gas or vapor," USSR Inventor's Certificate No. 162,813, IPC B 01 D 3/22; 3/26.
12. "Contact plate for mass-exchange reactors," USSR Inventor's Certificate No. 1,088,738, IPC B 01 D 3/22.

13. "Contacting of gases with liquids and liquid solids," Patent Great Britain 1,156,067, IPC B 01 D 3/22.
14. "Column plate," Patent GDR 59,773, IPC B 01 D 3/20.
15. "Elastic column baffle for diffusion separations," Patent CSSR 126,166, IPC B 01 D 3/20.
16. "Column plate," Patent Hungary 182400, IPC B 01 D 3/26.
17. "Regular packing for mass-exchange column," Patent France 2,366,859, IPC B 01 D 3/22; 53/18.
18. "Plate for contacting of moving streams," Patent Great Britain 1,342,512, IPC B 01 D 3/22.
19. "Contacting device," USSR Inventor's Certificate No. 1,064,964, B 01 D 3/30.
20. "Device for the washing of precopitates," USSR Inventor's Certificate No. 703,119, IPC B 01 D 21/02; C 02 C 3/00.
21. "Column reactor for the contacting of solids with a liquid," USSR Inventor's Certificate No. 858,857, IPC B 01 D 3/32; B 01 J 19/00.
22. T. A. Malinovskaya, V. V. Reinfart, I. A. Yakubovich, et al., "Washing of precipitates of organic intermediate products and dyestuffs in column reactors," Khim. Promst'., No. 5, 381-383 (1978).
23. "Contacting device for the countercurrent contacting of liquids," Patent FRG 1,088,927, IPC B 01 D 3/22.
24. "Internal arrangement of a column reactor," Patent Germany 744,183, IPC B 01 D 3/22.
25. "Column with sieve plates", Patent FRG 1,103,299, IPC B 01 D 3/22.
26. P. A. Sial and A. I. Gur'yanov, "Dynamics of mobile elements of contacting devices for pulsating extractors," Khim. Neft. Mashinostr., No. 7, 5-6 (1988).
27. "Scrubber," Patent Great Britain 1,204,781, IPC B 01 D 53/20.
28. "Contacting device," Patent CSSR 106,313, IPC B 01 D 3/40.
29. "Device for the contacting of a gas and a liquid," Patent Japan 61-6682, IPC B 01 D 3/32; 53/18, B 63 J 5/00.
30. "Column reactor for the reaction of solids with a liquid," USSR Inventor's Certificate No. 1,529,493, IPC B 01 D 3/22.
31. "Bell-shapped packing for mass-exchange processes," USSR Inventor's Certificate No. 217, 364, IPC B 01 D 53/20.
32. "Device for the contacting of a gas and a liquid," Patent Great Britain 1,065,554, IPC B 01 D 3/22.
33. "Gas—liquid contacting device," Patent Canada 1,197,172, IPC B 01 D 3/22.

FROM THE EDITOR

A. A. Bulanov's article is devoted to the analysis of the design of plates for mass-exchange columns, based on a review of the patent literature. However, the possibility of applying individual designs, described in the article, to liquid—solid systems is problematic. By publishing the article for discussion, the editor invites specialists to express their opinion about the problems touched in the article.