IMPROVING SOLIDS SUSPENSION USING DEFLECTING BAFFLES IN GASLIFT LOOP REACTORS①

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ABSTRACT In laboratory gaslift loop reactors, the gas flow rate for generating critical suspension of solid particles, Q_c, was measured in order to assess the energy efficiency for suspending solids. Three loop reactors were installed with bottoms of different shapes, and can be operated in two modes: either upflow or downflow in the central draft tube. Tap water, ion-exchange resin and fine gold ore concentrate were used as liquid and solid phases respectively. The study was focused on the effect of deflecting baffles fitted on the lower end of the draft tube. The results of measurement indicated that deflecting baffles near the bottom promoted swirling liquid flow over the bottom, led to significant reduction (50% ~ 90%) of Q_c and improved suspension of solids. The advantages of lower energy consumption and better solids suspension by installing deflecting baffles may benefit the general commercial processes in chemical, biotechnological and metallurgical industries.

Key words loop reactor deflecting baffles swirling flow

1 INTRODUCTION

The gaslift loop reactor has now been widely adopted in chemical and biochemical processing for its advantages such as simple construction, no mechanical agitation, more uniform distribution of shear rate and better energy efficiency of mixing. Diversified types of internal loop reactors with flat, conic or ellipsoidal bottoms are being used in industrial applications. Since the intensity of liquid phase agitation varies from point to point at the bottom, solid particles are prone to sedimentate at the spot with insufficient agitation, forming a "false" bottom and decreasing the reactor capacity[1]. The sedimentation of solid phase reactant leads easily to fouling and scaling, which deteriorates the reactor performance and sometimes forces reactors out of operation. The trouble of the "false" bottom is also present for the operation of stirred-tank reactors with a mechanical agitator. In order to optimize the operation and design of gaslift loop reactors, it is necessary to conduct thorough investigation on efficient suspension of solid material in loop reactors and other liquid-solid processing vessels.

We have reported that the bottom geometry and the direction of circulation in loop reactors show strong influence on the suspension of solid particles[2,3]. For an internal loop reactor with a flat bottom, when the liquid flows upward in the central draft tube (referred to as the upflow mode of operation), solid material is more likely to sedimentate on the center region of the bottom, whereas the peripheral corner at the bottom is the location for the sedimentation to appear first when the liquid flows downward in the draft tube (the downflow mode). Increasing the rate of air agitation helps to decrease the amount of sedimentation, but this also leads to drastic increase of energy consumption. Besides, reduction of solid precipitation becomes progressively difficult and inefficient as the last bit of sediment is to be eliminated by enhanced circulation only.

In this paper, experimental investigation on the effect of deflecting baffles installed in a new design of the loop reactor[4] is presented. The results indicate that the deflectors promote swirling and turbulence of recirculating liquid flow over the reactor bottom, so that the ability of the reactor to suspend solid particles is en-

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hanced without increasing the energy input.

2 EXPERIMENTAL

The experimental loop reactor made of plexiglass has either a flat bottom (a) or a frustoconic bottom with different depths (shallow frustum (b) and deep frustum (c)) as sketched in Fig. 1. The reactor is 720 mm high and its internal diameter (I. D.) is 102 mm. The central draft tube is a piece of plexiglass tube with 60 mm I. D., 5 mm wall thickness and 560 mm length, and installed 20 mm above the bottom. The frustoconic bottoms with the conic angle of 90° are 16 mm and 24 mm deep respectively for bottoms (b) and (c). A small porous ceramic block is fixed at the lower end of the draft tube as the gas sparger to induce the upflow circulation. For the downflow mode of operation, a ring sparger is installed at the lower end of the annulus to drive downward circulation through the draft tube. The draft tube with 6 deflecting baffles installed on the outer wall at the lower end is used for upflow operation, and 4 similar deflectors are arranged inside the draft tube when the downflow operation is desired. All the deflectors are curve-shaped so that they may deliver gradually to the axially flow liquid a tangential velocity component. The lower part of the deflectors is inclined to the reactor axis roughly at 45° angle (Fig. 2).

The solid particles used in the experiments are cation ion-exchange resin of low density. The density of the wet resin is between 1240 and 1 kg/m^3, and the size of particles over 95% (in mass) is in the range of 0.3 to 1.2 mm. Gold ore concentrate was chosen as the high density testing material, which had an average size of 0.114 mm with 80% (in mass) particles in the range of − 100 and + 240 mesh. The solid density was determined to be 3030 kg/m^3. Tap water was used in experiments, and the liquid level was always controlled to be 25 mm above the upper edge of the draft tube before the aeration started to create a solid-liquid circulating flow.

Experiments were run to determine the aeration rate for critical suspension of solid particles of various volumetric fractions in various cases with and without deflecting baffles. Three different criteria may be adopted for judging the critical status of solid suspension in experiments: uniform, off-bottom, and in-motion solids suspension[5].

The last one is most convenient for visual observation, since an observer can easily differ particles lying statically over the bottom from those in motion but has difficulty in judging the status of uniformity of solid suspension or distinguishing between particles sliding on the bottom and those slightly suspended above the bottom. There is evidence that the agitation behavior such as agitating power required for critical suspension is quite parallel for the measurements when either of these 3 criteria is adopted[5]. In this work, the in-motion criterion was adopted for judging the critical suspension.

Fig. 1 Experimental loop reactors

1, 2 —gas sparger

Fig. 2 Deflecting baffles at the lower part of the draft tube

(a) —upflow operation; (b) —downflow operation

3 RESULTS AND DISCUSSION

In the same reactor, experiments were conducted with different loadings of ion-exchange resin to investigate the effects of the mode of operation and the presence of deflectors on the aeration rate for critical suspension, Q_c. The results listed in Table 1 indicate that the deflectors can reduce the values of Q_c by a large extent for all the cases tested, no matter whatever the geometry of the reactor bottom and the operation mode (upflow or downflow) are tested.

Since the net power consumption for agitation is proportional to the aeration rate, the installation of deflecting baffles above the reactor bottom can thus reduce significantly the power input for creating critical suspension of solids, because the deflectors help to enhance the ability of loop reactors to suspend the particles at the location where gaslift driven axial circulation has weak effect. Q_c for the upflow operation in a flat bottom reactor with deflectors is reduced by 90% on the average (6 datum points). The reduction amounts to 80% (averaged over 5 data) for the downflow operation with bottom (b). Fig. 3 presents the effect of the volumetric solid loading on the critical aeration rate.

Visual observation through the transparent plexiglass bottom reveals that the pattern of particle motion on the bottom is different for the cases with and without deflectors (Fig. 4). Taking the upflow operation on the flat bottom as an example, liquid flows downwards in the annulus, impinges with inertia onto the bottom and is forced to turn to the center region of the bottom, which is the most difficult area for solid particles to be suspended. However, the installed deflectors append swirling with substantial tangential velocity component to the axial circulation, forming the swirling centripetal flow over the bottom. It is conjectured that the overall agitation intensity, presumably the combined turbulence intensity and wall shear stress, is enhanced at the center, since the swirling of the centripetal flow is intensified as it approaches the center due to the conservation of angular momentum. For the downflow operation in a reactor with a flat bottom, the corner (point N in Fig. 1) is the most difficult area for suspension of solids. When there is no deflecting baffles, N is a stagnant point in the flow field where the shear rate approaches to zero along either the bottom surface or the vertical wall. This is disadvantageous to suspension of solid particles. After a swirling component of flow is generated by the deflectors, N is no longer the stagnant point with zero shear rate, and the suspension of solids is expected to become easier. Although points M and N (in Fig. 1) are not stagnant points for the

Table 1 Comparison of critical aeration rates (Q_c) for solid suspension experiments(m^3/h)

Solid loading V / %			0.014	0.042	0.084	0.126	0.169	0.211
Flat bottom(a)	Upflow	no deflector	0.25	0.45	0.65	0.73	0.75	0.80
		with deflector	0.04	0.05	0.055	0.065	0.075	0.09
	Downflow	no deflector	0.63	0.81	0.91	–	–	–
		with deflector	0.13	0.135	0.20	0.25	0.32	0.34
Shallow bottom(b)	Upflow	no deflector	0.30	0.60	0.75	0.90	–	–
		with deflector	0.016	0.028	0.056	0.068	0.068	0.076
	Downflow	no deflector	0.25	0.43	0.61	0.75	079	–
		with deflector	0.08	0.105	0.125	0.15	0.165	0.185
Deep bottom(c)	Upflow	no deflector	0.38	0.63	0.81	0.88	–	–
		with deflector	0.016	0.026	0.052	0.064	0.068	0.076
	Downflow	no deflector	0.91	–	–	–	–	–
		with deflector	0.11	0.14	0.17	0.25	0.27	0.29

Fig. 3 Effects of deflecting baffles on critical air flow rate in the downflow operation
1 —no baffles, deep frustum bottom(c);
2 —no baffles, flat bottom(a);
3 —no baffles, shallow frustum bottom(b);
4 —baffled, flat bottom(a);
5 —baffled, deep frustum bottom(c);
6 —baffled, shallow frustum bottom(b)

Fig. 4 Sketches of flow patterns on the flat bottom in the upflow operation
(a) —no baffles; (b) —baffled

cases with frustum bottoms, installation of deflecting baffles promotes swirling flow on the bottom and increases the magnitude of wall shear stress, driving the otherwise stationary solid particles in motion.

Installation of deflectors changes the flow pattern in the loop reactors, so does the quantitative effect of bottom configuration on the solid suspension in the reactors. For the upflow operation, the suspending ability of the loop reactor without deflectors decreases in the order of (a) > (b) > (c) (Fig. 1), in contrast to the negligible difference between them when baffles are installed. For the downflow operation, the suspending ability without deflectors decreases in the order of (b) > (a) > (c), but the order is altered to give (b) > (c) > (a) (Fig. 3) when baffles are installed. Perhaps we have to resort to the computational fluid dynamics approach for ultimate understanding the quantitative interaction between particle suspension and the influencing factors such as the reactor geometric configuration and the installed internals. This is a difficult but inevitable step before the problem of optimizing the design of liquid-solid reactors is resolved.

Experiments were also performed in a 10 L capacity internal loop reactor with 117 mm I. D. and 1035 mm height, which was installed with a draft tube with dimension of d 53 mm × 880 mm. A ring-shaped sparger was fixed in the center over the bottom. Gold ore concentrate 50 g and tap water 10 L were loaded into the reactor. When no deflector was installed, the air aeration rate of 2.5 m^3/h did not suffice to reach the criterion of in-motion suspension and a lot of particles lay statically on the bottom center. However, installation of 8 deflectors in the lower end of the annulus reduced Q_c to 1.2 m^3/h for reaching the status of in-motion suspension, saving at least 50% of the agitating energy cost.

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