FLUIDIZED BED APPARATUS

The present invention relates to fluidized bed apparatus and an improvement in reducing the solid particles entrained out from the fluidized bed apparatus during operation along with the upward gas stream forming the fluidized bed.

As is well-known, fluidized bed apparatus comprises a vertical cylindrical vessel including mainly a gas supply, gas distributor, a fluidized bed portion (fluidized bed) and a free board.

The fluidized bed is a zone of solid particles fluidized by an upward gas stream. The fluidized bed apparatuses are used in various fields, for example, production of high-octane gasoline by cracking a high boiling point fraction above kerosene with a fluidized catalyst (which is generally known as the FCC process), production of a gas mainly composed of olefin by cracking a heavy oil of petroleum with fluidized heating medium solid particles, drying of wet solid granules by fluidizing with high temperature gas, synthesis of acrylonitrile by reacting propylene, ammonia and oxygen (air) with a fluidized catalyzer composed of a metal salt of a phosphomolybdic acid or phosphotungstic acid, and production of α-olefin polymers by polymerizing α-olefins in the fluidizing bed containing solid polymerization catalyst.

In any method, if drift of fluidized solid particles from the apparatus along with the upward gas

stream is excessive, many disadvantages are caused. That is, it becomes necessary to provide a device for separating the solid particles entrained from the gas passed through the apparatus, and further, a device for recycling separated particles to the fluidized bed.

As a result of intensive investigations, in order to overcome these disadvantages, there has been found a method of reducing entrainment of particles from the fluidized bed apparatus, by placing a specified internal baffle structure, which may hereinafter be referred to as an "internal", in the free board of the fluidized bed apparatus, thereby causing the particles accompanying the gas to impinge against it.

Hereinafter, the present invention will be described by exemplifying the method for polymerizing an α-olefin in a fluidized bed reactor, which is a kind of fluidized bed apparatus.

Polymerization of α-olefin by means of a fluidized bed reactor has been previously proposed.

That is, as proposed in Japanese Examined Patent Publication No 24679/1968 or 597/1966, when the fluidized gas flow rate is relatively low, not more than 15 cm/sec, a method has been proposed to prevent chunk formation by using an agitator so as to mix the particle bed uniformly.

Generally, however, it is difficult to mix powder uniformly by agitator, and an enormous agitating power is needed to achieve such uniform mixing in the reactor as the

proposed one. Besides, designing of the shape of agitating blades is very complicated and difficult.

A method to overcome such problems has been proposed in Japanese Examined Patent Publication No 13962/1972, wherein as far as the fluidizing gas flow velocity is sufficiently higher, as high as about 1.5 to 10 times, than the minimum fluidization velocity (Umf) of polymer particles, a stable fluidized bed may be obtained easily without particularly using any agitator. Nevertheless, as the fluidizing gas flow velocity increases, the ejection height of solid particles from the fluidized bed becomes higher, so that the number of particles entrained from the reactor increases extremely.

As the method of solving this problem, in turn, installation of velocity reduction zone expanding the cross-sectional area of the fluidized bed has been proposed. But prevention of entrainment in this method requires an extremely large volume of the free board in the reactor, and if such large volume is realized, the productivity of the reactor per unit volume is significantly lowered and the quantity of monomer to be purged notably increases when changing the monomer composition.

In another technique, a method of placing an internal baffle structure in the free board has been proposed. That is , according to Japanese Examined Patent Publication No 48151/1976, installation of internal members

composed of bar or tube members arranged in the horizontal direction in multiple stages has been proposed. In this method, the projected area ratio of the whole structure is set over 0.4 by keeping the projected area ratio of one stage of internal members to the cross-sectional area of free board below 0.5 and placing them in three or more stages. Even in this method, however, since the entrainment preventive effect per stage is small and the ascending gas flows in a route to surround the internals even if placed in multiple stages, impingement efficiency of particles decreases and, in effect, the entrainment preventive effect is small. Therefore, in order to obtain a sufficient effect in this method, it is necessary to increase the number of stages, but even then the large volume of free board remains a problem.

The aim of the present invention is to reduce said defects and substantially increase the productivity of the reactor per unit volume.

According to the present invention, there is provided a fluidized bed apparatus in which solid particles are fluidized by means of an ascending gas stream including means for reducing the amount of solid particles discharged from the apparatus by entrainment in the gas stream, such means including a rotatable baffle structure located within the apparatus above the fluidized bed, the structure having a projected area not less than 0.8 of the cross-section of the apparatus and the structure offering a passage for gas

of which the area is in the range 0.3 to 0.9 of the cross-sectional area of the apparatus wherein the structure is one of (a) the combination of a disc and a ring, (b) a tuyere-like structure of conical form or (c) a fan structure.

The invention also provides a method of reducing particle entrainment in a fluidized bed apparatus employing an ascending gas stream, by locating a rotating baffle structure within the apparatus above the fluidized bed so as to be contacted by the ascending stream, the structure having a projected area not less than 0.8 of the cross-section of the apparatus and the structure offering a passage for gas of which the area is in the range 0.3 to 0.9 of the cross-section area of the apparatus and the structure being one of (a) the combination of a disc and a ring, (b) a tuyere-like structure of conical form or (c) a fan structure, whereby particles contacting the structure tend to return to the bed and to be removed from the stream.

Preferably, the rotatable baffle structure is an assembly of blades inclined at such an angle to the axis of the apparatus as to enhance downward discharge of solid particles upon rotation.

Preferably the blades of the rotatable baffle structure are inclined at more than the angle of repose of the particles of the bed to a plane perpendicular to the structure axis.

The opening proportion referred to in this invention is defined as the ratio of the area of the narrowest passage capable of passing gases to the cross-sectional area of the free board.

The internal baffle structure may be a combination of blades making an angle to the horizontal larger than the angle of repose of particles (more than 30° in ordinary α-olefin particles). Furthermore, the most preferable internal baffle structure is a combination of blades having such an angle that a downward discharge flow is developed when the structure is rotated, with the spacing of neighbouring blades being very narrow or the blades partially overlapping when projected on the horizontal plane. In this case, since the projected area ratio to the free board cross-sectional area and the opening proportion can be quite large even in one stage, it is possible to significantly reduce the volume of the free board.

The requirements and features of the present invention are described more specifically below.

(1) The baffle structure or "internal" in the present invention may be preferably applied to a fluidized bed apparatus which is fluidized by an ascending stream of gas in the range of 1.0 to 10.0 times the minimum fluidization velocity of particles (abbreviated as Umf).

(2) The projected area ratio on the horizontal plane of the installing place of the internal to the free

board cross-sectional area is closely related with the entrained amount of solid particles. By controlling the projected area ratio above 0.8, or preferably above 0.9, the entrainment of solid particles from the reactor may be significantly reduced.

(3) When the opening in the internal is small relative to the free board cross-sectional area the particles contacting the internal tend not to return to the fluidized bed, but remain on the internal surface, so that the entrainment from the reactor is rather increased. As the result of investigations by the present inventors, it has been found that by keeping the flow of gas at the opening portion of the internal below the terminal velocity of particles, the amount of particles deposited on the internal can be significantly reduced. More specifically, favorable results will be obtained by keeping the opening proportion to the free board sectional area above 0.3, preferably above 0.5.

(4) The internal is rotated. Especially in the case of an assembly of plates inclined at such an angle as to develop downward discharge flow, larger downward moving energies can be applied to the particles by impingement when rotated, as compared with the case of fixed insert, so that the entrainment preventive effect is greatly enhanced. Another effect of rotation is in separation of particles deposited or accumulated on the surface of the internal. The larger the rotating speed, the greater becomes the

effect. But if the speed is too high, vortex flows increase, which cause increased deposition on the wall surface. Accordingly, favorable results may be obtained when the peripheral speed of the end of internal is in the range of 50 to 500 cm/sec.

The present invention is described in further detail below by referring to the drawings in which Figure 1 shows the vertical section view of one embodiment of a fluidized bed apparatus; Figures 2a and 3a show top views of a baffle structure or internal of tuyere structure having a conical form and an internal of propeller structure, respectively; Figures 2b and 3b are the side views of the same; Figures 2c and 3c show a 45° oblique view from the horizontal plane. Figures 4 and 5 illustrate internal consisting of disc and ring; Figure 6 shows one example of disc body and Figure 7 exemplifies the ring body.

The following symbols are used in the drawings:

D_T: inside diameter of fluidized bed apparatus (free board)

D_1: inside diameter of ring

D_2: diameter of disc

H_1: distance from disc to ring

1 : fluidized bed apparatus

2 : gas inlet

3 : gas distributor

4 : fluidized bed

5 : free board

6 : internal

7 : gas outlet.

First referring to Figure 2, the internal in tuyere structure having a conical shape shown in the top and side and 45° oblique view outline drawings are provided with the following conditions.

1) The projected area ratio to the free board cross-sectional area, $[D_T-2\ell_1)/D_T]^2$, is not less than 0.8, preferably not less than 0.9.

Herein, ℓ_1 is distance from the end of the longest blade of the insert of tuyere structure to the inner wall of the fluidized bed type reactor.

2) The number of blades is not specifically limited, but the adjacent blades are overlapped with each other when projected on a horizontal plane.

3. The internal is a part of the section including the apex of a cone, and an assembly of triangular or polygonal blades including the ridges, of which opening proportion is not less than 0.3, preferably not less than 0.5.

4) The inclination angle of the cone is larger than the angle of repose of particles, and it is desired to have an inclination angle of not less than 30°.

5) The blades may be planar, but may be also bent in waveform or arch-like structure, or of tube material.

6) Said internal mentioned in 1) to 5) may be also structured in an inverted conical form.

Figure 3 shows an outline drawing of an internal of propeller fan structure consisting of a combination of inclined blades. The internal is an assembly of blades inclined more than the angle of repose (45^{o} in Figure 2) with respect to the horizontal plane. The internal in Figure 3 satisfies the conditions 1), 2), 5) and 6) in Figure 2.

The internal is most preferably an assembly of inclined blades to minimize entrainment of solid particles, but structures shown in Figure 4 and Figure 5 may be also be applicable.

Figure 4 is an outline drawing of an internal composed of disc and ring, of which conditions are as follows:

1) The ring is determined so that its outside diameter may be equal to the tower diameter of the reactor D_T and that the inner diameter (D_1) may set the opening proportion $[(D_1/D_T)^2]$ not less than 0.3, or preferably not less than 0.5.

2) The disc, sharing the same center with the ring, has its diameter (D_2) determined so that the opening proportion $[(D_T^2-D2^2)/D_T^2]$ may be not less than 0.3, preferably not less than 0.5, and has D_1 and D_2 determined so that the projected area ratio on the horizontal plane to the free board cross-sectional area, $1-(D_1^2-D_2^2)/D_T^2$, may

be not less than 0.8.

3) The spacing H_1 between the ring and disc is determined so that the opening proportion $[4D_1H_1/D_T^2)]$ may be not less than 0.3, preferably not less than 0.5.

4) The disc may be situated above the ring as shown in Figure 4, or below it.

5) The combination may be one disc and one ring as shown in Figure 4, or two rings and one disc, for instance, as shown in Figure 5. The spacing of stages conforms to 3), and the diameter of disc and inside diameter and outside diameter of ring conform to 1) and 2). The structure may consist of more than two stages.

6) The disc may be a flat body, or may be bent in waveform or arch-like structure. Or a conical form wider than the angle of repose as shown in Figure 6 may be preferable.

7) The ring may be a flat body, or may be bent in waveform or arch-like structure. Or a structure inclining more than the angle of repose toward the center as shown in Figure 7, may be preferable.

The rotatable baffle structure or internal of the present invention is not limited to the structures described in Figs 2, 3 and 4, but it is sufficient that the projected area ratio on the horizontal plane of the internal to the free board sectional area be not less than 0.8, preferably not less than 0.9. By placing such internal in the free board of a fluidized bed apparatus,

the effect of preventing the solid particles from entraining above the internal may be substantially obtained.

Hereunder, the present invention is described in further detail referring to the Examples and Comparative Examples.

Example 1

In a glass fluidized bed apparatus measuring 20 cm in inside diameter and 150 cm in height, an internal having the structure shown in Figure 2 was placed at a position of 60 cm from the gas dispersion board (gas distributor).

In the structure of the internal, the inclination angle of the sides of the cone to the horizontal was 60°, the height about 20.4 cm, and the number of blades was 16. When projected on the horizontal plane, the blades overlapped with each other at a maximum of 5 mm, and the maximum length of blades projected on the horizontal plane in the radial direction was 9.5 cm from the center. The projected area ratio of the internal to the free board cross-sectional area on the horizontal plane was 0.9, and the opening proportion to the free board sectional area was 0.64. The internal was mounted on the rotating shaft. This fluidized bed apparatus was filled with 6 kg of polypropylene particles of almost spherical form with average particle size of 570 microns. The stationary bed height of particles at this time was about 40 cm.

Then, under atmospheric pressure, demoistured air used as fluidizing gas was supplied from the lower part of the gas dispersion board (gas distributor) at the free board velocity of 40 cm/sec, and the rotating shaft was rotated at a rate of 241 rpm . In this setting, ejection height of particles was visually observed, and no particles ejected further than 36.5 cm from the top of the internal, that is, from the surface of stationary bed.

Meanwhile, the minimum fluidization velocity of the particles used was 10 cm/sec.

Comparative Example 1

Without installing an internal, the same fluidized bed apparatus as in Example 1 was used, and the particle ejection height was measured under the same conditions, using the same particles as in Example 1.

The steady height of particles ejecting above was about 60 cm from the surface of particle stationary bed height, and some particles ejected even about 95 cm high occasionally.

Example 2

In a fluidized bed type reactor measuring 50 cm in inner diameter and 300 cm in height, an internal having a structure as shown in Figure 2 was placed at a position of 150 cm high above the dispersion board. In the structure of the internal, the inclination angle of the cone was 60°, the height was about 51 cm, and the number of blades was 16. When projected on the horizontal plane, the

blades overlapped with each other at the maximum of 8 mm, and the maximum length of the blades was 24 cm in the radial direction from the center. The internal was mounted on the rotating shaft. The projected area ratio on the horizontal plane of the internal to the free board cross-sectional area and opening proportion were respectively 0.92 and 0.66.

This fluidized bed type reactor was filled with 100 kg of polypropylene particles of nearly spherical form, of which average particle size was 570 microns. At this time, the stationary bed height of particles was measured by fiberscope observation in the apparatus, and was 115 cm.

Then pressurizing up to 15 kg/cm^2G (gauge pressure) with ethylene, the circulating gas compressor provided in said reactor system was operated to supply circulating gas from the lower part of the gas distributor to fluidize the particles while rotating the rotating shaft at a rate of 80 rpm. In this condition, the particle ejection height was measured.

In the measurement, cup-shaped particle collectors with a bottom measuring 4.5 cm in inner diameter and 4.5 cm in height were linked with chain at 10 cm intervals, and suspended from the upper part of the reactor, and were taken out after fluidizing at specified gas flow rate for 30 minutes. The particle ejection height was determined from the capturing state in each cup.

In this method, by varying the gas flow rate in

the range of 80 to 140 m^3/hr, the particle ejection height from the top of the stationary bed was determined. As the result, no particles were captured above the internal. The minimum fluidization velocity at this pressure was about 40 m^3/hr.

Comparative Example 2

Without installing the internal, the same fluidized bed type reactor as in Example 2 was used, and the particle ejection height was measured under the same conditions, using the same particles as in Example 2. The results are shown below.

Gas flow rate m^3/hr	Particle ejection height cm
80	90
110	120
140	160

Example 3

Using the same reactor as in Example 2, an internal having a structure as shown in Figure 3 was placed at a position of 150 cm from the gas distributor. In the structure of the internal, the inclination angle of the blades to the horizontal was 45°, the width of the blade at its top was 150 mm, and the number of blades was 16. When projected on the free board cross-section, the blades overlapped with each other at the maximum of 20 mm, and the maximum length in the projected view was 24 cm in the radial direction from the center. The internal was mounted on the rotating shaft, as in the case of Example 3. The

projected area ratio on the horizontal plane of the internal to the free board cross-sectional area and opening proportion were respectively 0.92 and 0.78.

Exactly in the same manner as in Example 2, polypropylene particles were fluidized, and the gas flow rate was varied in the range of 80 to 140 m/hr. Particle ejection height was measured in this state. The internal was rotated at a rate of 80 rpm.

As a result of measurement, particles were scarcely captured above the internal.

C L A I M S

1. A fluidized bed apparatus in which solid particles are fluidized by means of an ascending gas stream including means for reducing the amount of solid particles discharged from the apparatus by entrainment in the gas stream, such means including a rotatable baffle structure located within the apparatus above the fluidized bed, the structure having a projected area not less than 0.8 of the cross-section of the apparatus and the structure offering a passage for gas of which the area is in the range 0.3 to 0.9 of the cross-sectional area of the apparatus wherein the structure is one of (a) the combination of a disc and a ring, (b) a tuyere-like structure of conical form or (c) a fan structure.

2. Apparatus according to claim 1, wherein the rotatable baffle structure is an assembly of blades inclined at such an angle to the axis of the apparatus as to enhance downward discharge of solid particles upon rotation.

3. Apparatus according to claim 2, wherein the blades of the rotatable baffle structure are inclined at more than the angle of repose of the particles of the bed to a plane perpendicular to the structure axis.

4. A method of reducing particle entrainment in a fluidized bed apparatus employing an ascending gas stream, by locating a rotating baffle structure within the apparatus above the fluidized bed so as to be contacted by

the ascending stream, the structure having a projected area not less than 0.8 of the cross-section of the apparatus and the structure offering a passage for gas of which the area is in the range 0.3 to 0.9 of the cross-section area of the apparatus and the structure being one of (a) the combination of a disc and a ring, (b) a tuyere-like structure of conical form or (c) a fan structure, whereby particles contacting the structure tend to return to the bed and to be removed from the stream.

5. A method according to claim 4, wherein the rotating baffle is an assembly of blades inclined at such an angle to the axis of the apparatus as to enhance downward discharge of solid particles upon rotation.

6. A method according to claim 5, wherein the blades of the rotating baffle structure are inclined at more than the angle of repose of the particles of the bed to a plane perpendicular to the structure axis.

7. Fluidized bed apparatus substantially as hereinbefore described with reference to and as shown by the accompanying drawings.

8. A method for reducing particle entrainment substantially as hereinbefore described with reference to the accompanying drawings.

* C L M S *