

Description

The invention relates to an apparatus for separating solid particles from a fluid.

Soviet Inventions Illustrated, Derwent Publications Ltd., Section Chemical, Week K03, abstract number 06666, J01, March 2, 1983 discloses a two-stage dust separator including a swirl chamber having a curved side wall, a tangential inlet and a solids outlet. A swirl tube extends from the swirl chamber to outside thereof, and swirl imparting means are provided in a cylindrical element arranged in the swirl chamber, said cylindrical element having a larger diameter than the swirl tube.

US-A-4015960 discloses a gas-liquid separator in the form of a cylindrical vessel with a tangential inlet, a liquid outlet, a gas outlet and swirl imparting means arranged below the gas outlet.

GB-A-2061773 relates to a particle separator consisting of a first swirl chamber with a tangential inlet and a solids outlet, and a second swirl chamber having a gas outlet and another solids outlet.

US-A-4205965 relates to a gas-solids separator consisting of a swirl chamber with a tangential inlet and a solids outlet, and two gas outlets extending from within the swirl chamber to outside thereof and in opposite directions.

EP-A-206 399 discloses an apparatus for separating solid particles from a mixture of fluid and solid particles, comprising a swirl chamber having a curved side wall provided with a tangential inlet for the mixture and a solids outlet, and two opposite end walls.

In operation a mixture of fluid and solid particles enters the swirl chamber of the known apparatus through its tangential inlet. The mixture flows along the curved wall between the tangential inlet and the solids outlet. Part of the solids is removed through the solids outlet. The path of these solid particles is less than the circumference at the inner surface of the wall. This results in a short residence time of these solid particles.

Inherent to the arrangement of the inlet opening and the outlet opening in the known apparatus is that during operation a relatively high percentage of solid particles, especially the finer particles, is discharged through the fluid outlet tube rather than through the solids outlet.

It is an object of the invention to provide an apparatus for separating solid particles from a fluid, wherein the residence time of the particles in the apparatus is short and wherein both the coarser and the finer particles are separated from the fluid.

To this end the apparatus for separating solid particles from a mixture of fluid and solid particles according to the invention is characterized in that the apparatus further comprises:

- a cyclone separator having a common central longitudinal axis with the swirl chamber, said cyclone separator including:
- a swirl tube extending through an end wall into the swirl chamber, said swirl tube having an open end arranged in the swirl chamber and a second solids outlet arranged outside the swirl chamber;
- a fluid outlet tube extending through the opposite end wall into the swirl chamber and having an inlet part arranged in the swirl tube; and
- swirl imparting means arranged in an annular space between the swirl tube and the inlet part of the fluid outlet tube, wherein the swirl imparting means are so arranged that during operation the rotation of the mixture in the swirl tube has the same direction as in the swirl chamber.

The apparatus according to the invention is particularly useful in a catalytic cracking process in which the residence time of the solid particles in the apparatus should be as short as possible to prevent further cracking to take place at the then very hot solid particles.

In the apparatus according to the invention the coarser particles and part of the finer particles are discharged directly through the solids outlet. The fluid and the remaining finer particles flow into the swirl tube, thereby passing the swirl imparting means. Thus the swirl of the mixture in the swirl chamber is intensified by the swirl imparting means, thereby creating a swirl in the swirl tube of a high angular velocity. The remaining solid particles are thrown towards the inner wall of the swirl tube by centrifugal forces, flow along this wall towards the solids outlet opening and are discharged through the said opening. Since the swirl in the swirl tube is of a high angular velocity, the diameter of the swirl tube can be relatively small. This diameter is directly related to the internal volume of the swirl tube and therefore the internal volume can also be relatively small. The combination of the high angular velocity of the mixture in the swirl tube and the small internal volume allows a very short residence time of the remaining solid particles in the swirl tube.

The invention will now be described by way of example in more detail with reference to the accompanying drawings, wherein:

Figure 1 shows schematically a longitudinal cross-section of the apparatus for separating solid particles from a fluid according to the invention; and

Figure 2 shows schematically a cross-section along the line II-II in Figure 1.

The apparatus for separating solid particles from a fluid comprises a housing 1 having a swirl

chamber 3 which has the shape of a body of revolution generated by a line in the form of an arc of a circle revolving around the central longitudinal axis 5 of the swirl chamber 3, which axis 5 extends horizontally. The swirl chamber 3 is provided with an inlet opening 7 in communication with a tangential inlet 9, and a primary solids outlet opening 11 in communication with a solids outlet 13, wherein the tangential inlet 9 and the solids outlet 13 are arranged on the lower side of the swirl chamber 3. The primary solids outlet opening 11 extends in axial direction over a substantial portion of the axial length of the swirl chamber 3.

A horizontal cyclone separator has a swirl tube 16 extending coaxially through the wall 18 of the swirl chamber 3 and having an open end 20 arranged in the swirl chamber 3. The swirl tube 16 is provided with a secondary solids outlet opening 22 arranged near the end 24 of the swirl tube 16 opposite to its open end 20. The expression "coaxially" is used to refer to having a common central longitudinal axis with the swirl chamber 3.

A fluid outlet tube 28 extends coaxially through the wall 30 at the opposite side of the swirl chamber 3 in a direction opposite to the direction in which the swirl tube 16 extends. The fluid outlet tube 28 has an inlet part 32 and an outlet part 34, which inlet part 32 extends into the swirl tube 16 and comprises a primary section 36 joined to the outlet part 34, a frustoconical section 38 joined to the primary section 36 and tapering from the primary section 36 to a secondary section 40 having a smaller diameter than the primary section 36.

Swirl imparting means in the form of swirl vanes 46 are arranged in the annular space between the outer wall of the primary section 36 of the inlet part 32 and the inner wall of the swirl tube 16. The orientation of the swirl vanes 46 is such that the swirl of a mixture in the swirl chamber 3 is intensified when the mixture passes from the swirl chamber 3 via the swirl vanes 46 into the swirl tube 16.

During normal operation a mixture of gas and solid particles is introduced into the swirl chamber 3 via the tangential inlet 9 and the inlet opening 7. The tangential inlet 9 in co-operation with the curved wall of the swirl chamber 3 imparts a primary swirl to the mixture, around the central longitudinal axis 5 of the swirl chamber 3. Part of the swirling solid particles flows along the inner surface of the curved wall and is discharged through the solids outlet 13.

The remaining mixture consisting of the remaining solid particles and the gas flows into the swirl tube 16 via its open end 20 and passes along the swirl vanes 46. These swirl vanes 46 impart a secondary swirl to the remaining mixture in the swirl tube 16, which secondary swirl has a higher

angular velocity than the primary swirl. The swirling remaining solid particles flow along the inner surface of the wall of the swirl tube 16 until they are discharged through the secondary solids outlet opening 22.

The gas is discharged from the swirl tube 16 through the fluid outlet tube 28.

The apparatus according to the invention is similarly operated when a mixture of liquid and solid particles is introduced in the apparatus.

In the apparatus according to the invention the primary swirl is stabilized in the swirl chamber 3 by the parts of the swirl tube 16 and the fluid outlet conduit 28 which extend into the swirl chamber 3.

In the apparatus shown in Figure 1 the projection of the boundary of the primary solids outlet opening 11 on the central longitudinal axis 5 overlaps the whole projection of the inlet opening 7 on this axis 5, wherein a projection of a boundary is obtained by intersecting straight lines a, b, c, d through every point of the boundary and perpendicular to the central longitudinal axis 5 with this axis 5.

Alternatively the projection of the boundary of the primary solids outlet opening on the central longitudinal axis may overlap only part of the projection of the inlet opening on this axis.

The line for the generation of the body of revolution may also be a straight line or an elliptical line.

The ratio of the inner diameter of the swirl tube 16 to the largest diameter of the swirl chamber 3 is suitably chosen between 0.15 and 0.75.

In the specification and in the claims the expressions "specific distance", "specific length" and "specific inner diameter" are used to refer to the ratio of these dimensions to the inner diameter of the swirl tube 16.

The specific length of the swirl tube 16 is preferably between 2.0 and 6.0.

The specific inner diameter of the fluid outlet tube 28 is preferably between 0.50 and 0.80.

Preferably the specific length of the inlet part 32 of the fluid outlet tube 28 is between 1.45 and 2.7.

The length of the part of the swirl tube 16 extending in the swirl chamber 3 is suitably smaller than 0.5 times the axial length of the swirl chamber 3, which axial length is the distance between the inner surfaces of the walls 18 and 30.

In a suitable embodiment of the apparatus according to the invention the specific length of the secondary section 40 of the inlet part 32 of the fluid outlet tube 28 is between 0.25 and 1.0, the specific length of the primary section 36 is between 1.0 and 1.4, and the specific inner diameter of the secondary section 40 is between 0.2 and 0.4.

The following experiments have been carried out to illustrate the improved operation of the apparatus according to the invention for separating solid particles from a fluid.

In Experiment 1 the expression "swirl number" is used to refer to the ratio of the tangential component of the velocity of the mixture to the axial component of the velocity of the mixture.

Experiment 1.

The apparatus according to the invention as used in this experiment had the following characteristics:

the swirl chamber had the shape of a part of a sphere intersected by two parallel planes at equal distances from the centre of the sphere, which planes were perpendicular to the central longitudinal

axis of the swirl chamber;

the largest diameter of the swirl chamber was 1.62 times its axial length;

the inner diameter of the swirl tube was 0.33 times the largest diameter of the swirl chamber;

the length of the swirl tube was 5.13 times its inner diameter;

and the inner diameter of the fluid outlet tube was constant throughout its length and was 0.65 times the inner diameter of the swirl tube.

A mixture of fluid and solid particles was supplied to the tangential inlet. The fluid had a density of 1.25 kg/m³ and the pressure difference between the fluid at the tangential inlet and in the fluid outlet tube was 1600 Pa. The mixture contained 7 kg/m³ solid particles having a mean diameter of 73 μm. The swirl number of the mixture when it passed the swirl vanes was 1.73. As a result it was found that 99.999 % of the solid particles was discharged through the solids outlet of the swirl chamber and through the solids outlet opening of the swirl tube, and the remaining part of 0.001 % through the fluid outlet tube.

Experiment 2 (comparison).

The apparatus used in this experiment was not provided with a swirl tube and thus had only one solids outlet. The fluid outlet tube debouched directly in the swirl chamber. This apparatus had the following characteristics:

the swirl chamber had the same shape as in experiment 1;

the largest diameter of the swirl chamber was 1.62 times its axial length;

and the inner diameter of the fluid outlet tube was constant throughout its length and was 0.22 times the largest diameter of the swirl chamber.

A mixture of fluid and solid particles was supplied to the tangential inlet. The fluid had a density

of 1.25 kg/m³ and the pressure difference between the fluid at the tangential inlet and in the fluid outlet tube was 800 Pa. The mixture contained 7 kg/m³ solid particles having a mean diameter of 73 μm. As a result it was found that 99.5 % of the solid particles was discharged through the solids outlet, and the remaining part of 0.5 % through the fluid outlet tube.

The results of Experiments 1 and 2 show that a significantly better separation was obtained using the apparatus according to the invention compared to the known apparatus.

Claims

1. An apparatus for separating solid particles from a mixture of fluid and solid particles, comprising:
 - a swirl chamber (3) having a curved side wall provided with a tangential inlet (9) for the mixture and a first solids outlet (13), and two opposite end walls (18, 30), characterized in that the apparatus further comprises:
 - a cyclone separator having a common central longitudinal axis (5) with the swirl chamber (3), said cyclone separator including:
 - a swirl tube (16) extending through an end wall (18) into the swirl chamber (3), said swirl tube (16) having an open end (20) arranged in the swirl chamber (3) and a second solids outlet (22) arranged outside the swirl chamber (3);
 - a fluid outlet tube (28) extending through the opposite end wall (30) into the swirl chamber (3) and having an inlet part (32) arranged in the swirl tube (16); and
 - swirl imparting means (46) arranged in an annular space between the swirl tube (16) and the inlet part (32) of the fluid outlet tube (28), wherein the swirl imparting means (46) are so arranged that during operation the rotation of the mixture in the swirl tube (16) has the same direction as in the swirl chamber (3).
2. Apparatus according to claim 1, wherein at least part of the swirl chamber (3) has the shape of a body of revolution generated by a line revolving around the central longitudinal axis (5).
3. The apparatus according to claim 2, wherein said part of the swirl chamber (3) has the shape of a body of revolution generated by an arc of a circle revolving around the central longitudinal axis (5).



The following experiments have been carried out to illustrate the improved operation of the apparatus according to the invention for separating solid particles from a fluid.

In Experiment 1 the expression "swirl number" is used to refer to the ratio of the tangential component of the velocity of the mixture to the axial component of the velocity of the mixture.

Experiment 1.

The apparatus according to the invention as used in this experiment had the following characteristics:

the swirl chamber had the shape of a part of a sphere intersected by two parallel planes at equal distances from the centre of the sphere, which planes were perpendicular to the central longitudinal axis of the swirl chamber;

the largest diameter of the swirl chamber was 1.62 times its axial length;

the inner diameter of the swirl tube was 0.33 times the largest diameter of the swirl chamber;

the length of the swirl tube was 5.13 times its inner diameter;

and the inner diameter of the fluid outlet tube was constant throughout its length and was 0.65 times the inner diameter of the swirl tube.

A mixture of fluid and solid particles was supplied to the tangential inlet. The fluid had a density of 1.25 kg/m^3 and the pressure difference between the fluid at the tangential inlet and in the fluid outlet tube was 1600 Pa. The mixture contained 7 kg/m^3 solid particles having a mean diameter of $73 \text{ }\mu\text{m}$. The swirl number of the mixture when it passed the swirl vanes was 1.73. As a result it was found that 99.999 % of the solid particles was discharged through the solids outlet of the swirl chamber and through the solids outlet opening of the swirl tube, and the remaining part of 0.001 % through the fluid outlet tube.

Experiment 2 (comparison).

The apparatus used in this experiment was not provided with a swirl tube and thus had only one solids outlet. The fluid outlet tube debouched directly in the swirl chamber. This apparatus had the following characteristics:

the swirl chamber had the same shape as in experiment 1;

the largest diameter of the swirl chamber was 1.62 times its axial length;

and the inner diameter of the fluid outlet tube was constant throughout its length and was 0.22 times the largest diameter of the swirl chamber.

A mixture of fluid and solid particles was supplied to the tangential inlet. The fluid had a density

of 1.25 kg/m^3 and the pressure difference between the fluid at the tangential inlet and in the fluid outlet tube was 800 Pa. The mixture contained 7 kg/m^3 solid particles having a mean diameter of $73 \text{ }\mu\text{m}$. As a result it was found that 99.5 % of the solid particles was discharged through the solids outlet, and the remaining part of 0.5 % through the fluid outlet tube.

The results of Experiments 1 and 2 show that a significantly better separation was obtained using the apparatus according to the invention compared to the known apparatus.

Claims

1. An apparatus for separating solid particles from a mixture of fluid and solid particles, comprising:

- a swirl chamber (3) having a curved side wall provided with a tangential inlet (9) for the mixture and a first solids outlet (13), and two opposite end walls (18, 30), characterized in that the apparatus further comprises:
- a cyclone separator having a common central longitudinal axis (5) with the swirl chamber (3), said cyclone separator including:
- a swirl tube (16) extending through an end wall (18) into the swirl chamber (3), said swirl tube (16) having an open end (20) arranged in the swirl chamber (3) and a second solids outlet (22) arranged outside the swirl chamber (3);
- a fluid outlet tube (28) extending through the opposite end wall (30) into the swirl chamber (3) and having an inlet part (32) arranged in the swirl tube (16); and
- swirl imparting means (46) arranged in an annular space between the swirl tube (16) and the inlet part (32) of the fluid outlet tube (28), wherein the swirl imparting means (46) are so arranged that during operation the rotation of the mixture in the swirl tube (16) has the same direction as in the swirl chamber (3).

2. Apparatus according to claim 1, wherein at least part of the swirl chamber (3) has the shape of a body of revolution generated by a line revolving around the central longitudinal axis (5).

3. The apparatus according to claim 2, wherein said part of the swirl chamber (3) has the shape of a body of revolution generated by an arc of a circle revolving around the central longitudinal axis (5).



4. The apparatus according to any one of the claims 1-3, wherein the specific inner diameter of the fluid outlet tube (28) is between 0.50 and 0.80.

5. The apparatus according to any one of the claims 1-4, wherein the specific length of the inlet part (32) of the fluid outlet tube (28) is between 1.45 and 2.7.

6. The apparatus according to any one of the claims 1-5, wherein the length of the part of the swirl tube (16) extending in the swirl chamber (3) is smaller than 0.5 times the axial length of the swirl chamber (3).

7. The apparatus according to any one of the claims 1-6, wherein the inlet part (32) of the fluid outlet tube (28) comprises a primary section (36) joined to a frustoconical section (38) tapering from the primary section (36) to an open-ended secondary section (40) having a smaller diameter than the primary section (36).

8. The apparatus according to claim 7, wherein the specific length of the secondary section (40) is between 0.25 and 1.0.

9. The apparatus according to any one of claims 7-8, wherein the specific length of the primary section (36) is between 1.0 and 1.4.

10. The apparatus according to any one of the claims 7-9, wherein the specific inner diameter of the secondary section (40) is between 0.2 and 0.4.

Patentansprüche

1. Vorrichtung zum Abscheiden von Feststoffteilchen aus einer Mischung aus einem Fluid und Feststoffteilchen, mit:

- einer Wirbelkammer (3) mit einer gekrümmten Seitenwand, die mit einem tangentialen Einlaß (9) für die Mischung und einem ersten Feststoffteilchenauslaß (13) ausgestattet ist, sowie mit zwei gegenüberliegenden Stirnwänden (18, 30), dadurch gekennzeichnet, daß die Vorrichtung weiters aufweist:
- einen Zyklonabscheider mit einer mit der Wirbelkammer (3) gemeinsamen zentralen Längsachse (5), welcher Zyklonabscheider enthält:
- ein Wirbelrohr (16), das sich durch eine Stirnwand (18) in die Wirbelkammer (3) erstreckt, wobei das Wirbelrohr (16) ein offenes Ende (20) hat, das in der Wirbel-

kammer (3) liegt, und einen zweiten Feststoffteilchenauslaß (22), welcher außerhalb der Wirbelkammer (3) liegt;

- ein Fluidauslaßrohr (28), das sich durch die gegenüberliegende Stirnwand (30) in die Wirbelkammer (3) hineinerstreckt und einen Einlaßteil (32) hat, der im Wirbelrohr (16) liegt; und
- Verwirbelungsmittel (46), die im Ringraum zwischen dem Wirbelrohr (16) und dem Einlaßteil (32) des Fluidauslaßrohres (28) angeordnet sind, wobei die Verwirbelungsmittel (46) so angeordnet sind, daß im Betrieb die Rotation der Mischung im Wirbelrohr (16) dieselbe Richtung wie in der Wirbelkammer (3) hat.

2. Vorrichtung nach Anspruch 1, bei welcher zumindest ein Teil der Wirbelkammer (3) die Form eines Drehkörpers hat, der durch eine Linie erzeugt ist, welche sich um die zentrale Längsachse (5) dreht.

3. Vorrichtung nach Anspruch 2, bei welcher der genannte Teil der Wirbelkammer (3) die Form eines Drehkörpers hat, der durch einen Kreisbogen erzeugt ist, welcher sich um die zentrale Längsachse (5) dreht.

4. Vorrichtung nach einem der Ansprüche 1 bis 3, bei welcher der spezifische Innendurchmesser des Fluidauslaßrohres (28) zwischen 0,50 und 0,80 beträgt.

5. Vorrichtung nach einem der Ansprüche 1 bis 4, bei welcher die spezifische Länge des Einlaßteiles (32) des Fluidauslaßrohres (28) zwischen 1,45 und 2,7 liegt.

6. Vorrichtung nach einem der Ansprüche 1 bis 5, bei welcher die Länge jenes Teiles des Wirbelrohres (16), der sich in die Wirbelkammer (3) erstreckt, kleiner als das 0,5-fache der Axiallänge der Wirbelkammer (3) ist.

7. Vorrichtung nach einem der Ansprüche 1 bis 6, bei welcher der Einlaßteil (32) des Fluidauslaßrohres (28) einen Hauptabschnitt (36) aufweist, der mit einem kegelstumpfförmigen Abschnitt (38) verbunden ist, welcher sich vom Hauptabschnitt (36) auf einen Hilfsabschnitt (40) mit offenem Ende verjüngt, der einen kleineren Durchmesser als der Hauptabschnitt (36) besitzt.

8. Vorrichtung nach Anspruch 7, bei welcher die spezifische Länge des Hilfsabschnittes (40) zwischen 0,25 und 1,0 liegt.



9. Vorrichtung nach einem der Ansprüche 7-8, bei welcher die spezifische Länge des Hauptabschnittes (36) zwischen 1,0 und 1,4 liegt.

10. Vorrichtung nach einem der Ansprüche 7 bis 9, bei welcher der spezifische Innendurchmesser des Hilfsabschnittes (40) zwischen 0,2 und 0,4 liegt.

Revendications

1. Appareil pour séparer des particules solides d'un mélange de fluide et de particules solides, comprenant:
 - une chambre de tourbillonnement (3) ayant une paroi latérale courbe pourvue d'une entrée tangentielle (9) pour le mélange et d'une première sortie de solides (13), et deux parois d'extrémité opposées (18, 30), caractérisé en ce que l'appareil comprend en outre:
 - un séparateur à cyclone ayant un axe longitudinal central (5) commun avec la chambre de tourbillonnement (3), ledit séparateur à cyclone comportant:
 - un tube à tourbillon (16) s'étendant à travers une paroi d'extrémité (18) dans la chambre de tourbillonnement (3), ledit tube à tourbillon (16) ayant une extrémité ouverte (20) disposée dans la chambre de tourbillonnement (3) et une seconde sortie de solides (22) disposée à l'extérieur de la chambre de tourbillonnement (3);
 - un tube de sortie de fluide (28) s'étendant à travers la paroi d'extrémité opposée (30) dans la chambre de tourbillonnement (3) et ayant une partie d'entrée (32) disposée dans le tube à tourbillon (16); et
 - des moyens pour imprimer un tourbillon (46) disposés dans un espace annulaire compris entre le tube à tourbillon (16) et la partie d'entrée (32) du tube de sortie de fluide (28), les moyens pour imprimer un tourbillon (46) étant disposés de telle sorte que pendant le fonctionnement la rotation du mélange dans le tube à tourbillon (16) ait le même sens que dans la chambre de tourbillonnement (3).
2. Appareil selon la revendication 1, dans lequel au moins une partie de la chambre de tourbillonnement (3) possède la forme d'un corps de révolution engendré par une ligne tournant autour de l'axe longitudinal central (5).

3. Appareil selon la revendication 2, dans lequel ladite partie de la chambre de tourbillonnement (3) possède la forme d'un corps de révolution engendré par un arc de cercle tournant autour de l'axe longitudinal central (5).

4. Appareil selon l'une quelconque des revendications 1 à 3, dans lequel le diamètre interne spécifique du tube de sortie de fluide (28) est compris entre 0,50 et 0,80.

5. Appareil selon l'une quelconque des revendications 1 à 4, dans lequel la longueur spécifique de la partie d'entrée (32) du tube de sortie de fluide (28) est comprise entre 1,45 et 2,7.

6. Appareil selon l'une quelconque des revendications 1 à 5, dans lequel la longueur de la partie du tube à tourbillon (16) s'étendant dans la chambre de tourbillonnement (3) est inférieure à 0,5 fois la longueur axiale de la chambre de tourbillonnement (3).

7. Appareil selon l'une quelconque des revendications 1 à 6, dans lequel la partie d'entrée (32) du tube de sortie de fluide (28) comprend une section primaire (36) reliée à une section tronconique (38) se rétrécissant à partir de la section primaire (36) jusqu'à une section secondaire ouverte à son extrémité (40) ayant un plus petit diamètre que la section primaire (36).

8. Appareil selon la revendication 7, dans lequel la longueur spécifique de la section secondaire (40) est comprise entre 0,25 et 1,0.

9. Appareil selon l'une quelconque des revendications 7 ou 8, dans lequel la longueur spécifique de la section primaire (36) est comprise entre 1,0 et 1,4.

10. Appareil selon l'une quelconque des revendications 7 à 9, dans lequel le diamètre interne spécifique de la section secondaire (40) est compris entre 0,2 et 0,4.