

PILLARED BODY SEPARATION METHOD AND PILLARED BODY SEPARATION DEVICE

BACKGROUND OF THE INVENTION

5 Field of the Invention

[0001]

The present invention relates to a pillared body separation method and a pillared body separation device that enables separation of two kinds of pillared bodies of which lengths and thicknesses are different from each other.

10 Priority is claimed on Japanese Patent Application No. 2012-062114, filed on March 19, 2012, the content of which is incorporated herein by reference.

Description of Related Art

[0002]

15 During reaction using solid catalysts, there are general cases in which pillared bodies as the solid catalysts and pillared bodies for dilution to adjust the reaction are filled inside a reactor. Deteriorated solid catalysts are taken out from a reactor to be replaced, and even recycled in recent years without being discarded. However, in order to recycle the used solid catalysts, it is necessary to separate the catalysts from pillared
20 bodies for dilution.

As a device that separates the two kinds of pillared bodies, for example, a device that includes a cylindrical sieve, drive means that causes the sieve to rotate, and supply means that supplies the two kinds of pillared bodies on an inner circumferential face of the sieve has been known(Patent Document 1).

25 In addition, as a sieve that separates pillared bodies, one that has round holes is

general, but Patent Document 2 discloses hexagonal, triangular, square holes, and the like.

[0003]

[Patent Document 1] Japanese Unexamined Patent Publication No. 9-123165

5 [Patent Document 2] Japanese Unexamined Patent Publication No. 10-84805

SUMMARY OF THE INVENTION

[0004]

10 However, there are cases in which the pillared bodies as solid catalysts and the pillared bodies for dilution have subtle differences in lengths and thicknesses thereof, and substantially the same shape. In such a case, separation of the two pillared bodies is difficult in the separation device described in Patent Document 1. In addition, even when the sieve described in Patent Document 2 is used in the separation of two kinds of
15 pillared bodies of which lengths and thicknesses are subtly different from each other, reliable separation cannot be performed.

The present invention aims to provide a pillared body separation method and a pillared body separation device that can reliably separate two kinds of pillared bodies of which lengths and thicknesses are different from each other, particularly, two kinds of
20 pillared bodies of which lengths and diameters have subtle differences.

[0005]

The present invention has the following aspects.

[1] A pillared body separation method for separating first pillared bodies each of which has a first end face and a second end face parallel with each other from second
25 pillared bodies each of which has a length and a thickness greater than those of the first

pillared body by using a sieve that has holes formed therein satisfying the following conditions (I) and (II):

(I) when a direction along an opening face of the sieve is set to a Y direction, a direction along an opening face of the sieve and vertical to the Y direction is set to an X direction, and a direction vertical to both of the X direction and the Y direction is set to a Z direction, and a virtual rotation axis A that penetrates the center of gravity of the first pillared body and is parallel with the first end face and the second end face of the first pillared body is disposed inside a hole so as to be along the X-Y plane, and the first pillared body is rotated around the virtual rotation axis A, each hole is a hole having a shape in which the first pillared body can rotate 360° without coming into contact with the sieve, regardless of the direction of the virtual rotation axis A within the X-Y plane, and

(II) when an area formed by projecting a first pillared body obtained after 360° rotation of the body around the virtual rotation axis A on the X-Y plane that includes the virtual rotation axis A is set to a first pillared body passing area, and the interval of edges of the hole that face each other in the direction of the virtual rotation axis A interposing the first pillared body passing area is set to D, the hole is a hole of which the minimum value of D is less than the length and the thickness of each second pillared body.

[2] A pillared body separation method for separating first pillared bodies each of which has a first end face and a second end face not parallel with each other and second pillared bodies each of which has a length and a thickness greater than those of each first pillared body using a sieve that has holes formed therein satisfying the following conditions (III) and (IV):

(III) when a direction along an opening face of the sieve is set to a Y direction, a direction that is along an opening face of the sieve and vertical to the Y direction is set to

an X direction, and a direction vertical to both of the X direction and the Y direction is set to a Z direction, and a virtual rotation axis A that penetrates the center of gravity of the first pillared body and is vertical to the longest straight line of the distance between the first end face and the second end face on a side face of the first pillared body is

5 disposed inside a hole so as to be along the X-Y plane, and the first pillared body is rotated around the virtual rotation axis A, each hole is a hole having a shape in which the first pillared body can rotate 360° without coming into contact with the sieve, regardless of the direction of the virtual rotation axis A within the X-Y plane, and

(IV) when an area formed by projecting a first pillared body obtained after 360° 10 rotation of the body around the virtual rotation axis A on the X-Y plane that includes the virtual rotation axis A is set to a first pillared body passing area, and the interval of edges of the hole that face each other interposing the first pillared body passing area in the direction of the virtual rotation axis A is set to D, the hole is a hole of which the minimum value of D is less than the length and the thickness of each second pillared 15 body.

[3] The pillared body separation method described in [1], in which the holes have a hexagonal shape.

[4] The pillared body separation method described in [2], in which the holes have a hexagonal shape.

20 [5] The pillared body separation method described in [1], in which the holes have an oblong shape.

[6] The pillared body separation method described in [2], in which the holes have an oblong shape.

[7] The pillared body separation method described in [3] or [4], in which the 25 holes satisfy all of the following conditions (a) to (d):

(a) each hole has pairs of sides facing each other which are parallel with each other and have the same length;

(b) the distance W between any side S_1 of the hole and a side S_2 that is parallel with the side S_1 is greater than the diameter and the length of each first pillared body and
5 smaller than the diameter of each second pillared body;

(c) when the direction of W is set to the X direction, the direction parallel with the side S_1 is set to the Y direction, and the direction vertical to both of the X direction and the Y direction is set to the Z direction, and the first pillared body is inserted into the hole so that the axis direction of the body is parallel with the Z direction and a rotation
10 axis is provided at the center of the axis direction, a length L_A of the side S_1 and the maximum length L_B of the hexagon in the Y direction are lengths in which an axis of the first pillared body can rotate so as to be along the Y - Z plane; and

(d) L_A and L_B are lengths in which each second pillared body cannot penetrate through the hole when the body is disposed on the hole so that the axis direction thereof
15 is along the X direction.

[8] The pillared body separation method described in [7], in which the first pillared body and the second pillared body are respectively columnar bodies.

[9] The pillared body separation method described in any one of [1] to [8], in which the sieve is a cylindrical sieve, the first pillared body and the second pillared body
20 are supplied to an inner circumferential face side of the cylindrical sieve, and the cylindrical sieve is rotated.

[10] The pillared body separation method described in [9], in which scale that is generated from at least one of the first pillared bodies and the second pillared bodies and adheres to the inner circumferential face of the cylindrical sieve is removed.

[11] The pillared body separation method described in [10], in which the scale is
25

removed by bringing a brush into contact with the inner circumferential face of the cylindrical sieve.

[12] The pillared body separation method described in [10], in which the scale is removed by tapping the cylindrical sieve with a hammer.

5 [13] A pillared body separation device that includes a sieve having holes that are formed therein satisfying the following conditions (I) and (II) and separates first pillared bodies each of which has a first end face and a second end face parallel with each other from second pillared bodies each of which has a length and a thickness greater than those of each first pillared body, the conditions are:

10 (I) when a direction along the opening face of the sieve is set to a Y direction, a direction along an opening face of the sieve and vertical to the Y direction is set to an X direction, and a direction vertical to both of the X direction and the Y direction is set to a Z direction, and a virtual rotation axis A that penetrates the center of gravity of the first pillared body and is parallel with the first end face and the second end face of the first
15 pillared body is disposed inside a hole so as to be along the X-Y plane, and the first pillared body is rotated around the virtual rotation axis A, each hole is a hole having a shape in which the first pillared body can rotate 360° without coming into contact with the sieve, regardless of the direction of the virtual rotation axis A within the X-Y plane, and

20 (II) when an area formed by projecting a first pillared body obtained after 360° rotation of the body around the virtual rotation axis A on the X-Y plane that includes the virtual rotation axis A is set to a first pillared body passing area, and the interval of edges of the hole that face each other in the direction of the virtual rotation axis A interposing the first pillared body passing area is set to D, the hole is a hole of which the minimum
25 value of D is less than the length and the thickness of each second pillared body.

[14] A pillared body separation device that includes a sieve having holes that are formed therein satisfying the following conditions (III) and (IV) and separates first pillared bodies each of which has a first end face and a second end face not parallel with each other from second pillared bodies each of which has a length and a thickness greater than those of each first pillared body, the conditions are:

(III) when one direction along an opening face of the sieve is set to a Y direction, a direction that is along the opening face of the sieve and vertical to the Y direction is set to an X direction, and a direction vertical to both of the X direction and the Y direction is set to a Z direction, and a virtual rotation axis A that penetrates the center of gravity of the first pillared body and is vertical to the longest straight line of the distance between the first end face and the second end face on a side face of the first pillared body is disposed inside a hole so as to be along the X-Y plane, and the first pillared body is rotated around the virtual rotation axis A, each hole is a hole having a shape in which the first pillared body can rotate 360° without coming into contact with the sieve, regardless of the direction of the virtual rotation axis A within the X-Y plane, and

(IV) when an area formed by projecting a first pillared body obtained after 360° rotation of the body around the virtual rotation axis A on the X-Y plane that includes the virtual rotation axis A is set to a first pillared body passing area, and the interval of edges of the hole that face each other interposing the first pillared body passing area in the direction of the virtual rotation axis A is set to D, the hole is a hole of which the minimum value of D is less than the length and the thickness of each second pillared body.

[15] The pillared body separation device described in [13] or [14], in which holes have a hexagonal shape, satisfying all of the following conditions (a) to (d):

(a) each hole has pairs of sides facing each other which are parallel with each

other and have the same length;

(b) the distance W between any side S_1 of the hole and a side S_2 that is parallel with the side S_1 is greater than the diameter and the length of each first pillared body and smaller than the diameter of each second pillared body;

5 (c) when the direction of W is set to the X direction, the direction parallel with the side S_1 is set to the Y direction, and the direction vertical to both of the X direction and the Y direction is set to the Z direction, and the first pillared body is inserted into the hole so that the axis direction of the body is parallel with the Z direction and a rotation axis is provided at the center of the axis direction, a length L_A of the side S_1 and the
10 maximum length L_B of the hexagon in the Y direction are lengths in which an axis of the first pillared body can rotate so as to be along the Y - Z plane; and

(d) L_A and L_B are lengths in which each second pillared body cannot penetrate through the hole when the body is disposed on the hole so that the axis direction thereof is along the X direction.

15 [0006]

According to the pillared body separation method and pillared body separation device of the present invention, two kinds of pillared bodies of which lengths and thicknesses are different from each other, particularly, two kinds of pillared bodies of which lengths and diameters show subtle differences can be reliably separated.

20

BRIEF DESCRIPTION OF THE DRAWINGS

[0007]

FIG. 1 is a schematic diagram showing an embodiment of a pillared body separation device according to the present invention.

25 FIG. 2 is a cross-sectional view obtained by cutting along the line I-I' of FIG. 1.

FIG. 3 is a plan view showing a hole of a cylindrical sieve included in the pillared body separation device shown in FIG. 1.

FIG. 4 is a perspective view illustrating the hole shown in FIG. 3.

FIG. 5 is another perspective view illustrating the hole shown in FIG. 3.

5 FIG. 6 is a plan view illustrating the hole shown in FIG. 3.

FIG. 7 is another plan view illustrating the hole shown in FIG. 3.

FIG. 8 is still another plan view illustrating the hole shown in FIG. 3.

FIG. 9 is still another plan view illustrating the hole shown in FIG. 3.

10 9. FIG. 10 is a cross-sectional view obtained by cutting along the line II-II' of FIG. 9.

FIG. 11 is a plan view illustrating the hole shown in FIG. 3.

FIG. 12 is a cross-sectional view obtained by cutting along the line III-III' of FIG. 11.

FIG. 13 is still another plan view illustrating the hole shown in FIG. 3.

15 FIG. 14 is a cross-sectional view obtained by cutting along the line IV-IV' of FIG. 13.

FIG. 15 is still another plan view illustrating the hole shown in FIG. 3.

FIG. 16 is still another plan view illustrating the hole shown in FIG. 3.

FIG. 17 is a plan view showing other examples of a hole.

20 FIG. 18 is a plan view showing the arrangement of holes according to Example 1.

FIG. 19 is a plan view showing the arrangement of holes according to Example 3.

25 FIG. 20 is a plan view showing the arrangement of holes of Comparative Example 1.

DETAILED DESCRIPTION OF THE INVENTION

[0008]

<Pillared Body Separation Device>

5 An embodiment of a pillared body separation device according to the present invention will be described.

FIGS. 1 and 2 show a pillared body separation device according to the present embodiment. The pillared body separation device 1 of the present embodiment is a device that separates first pillared bodies from second pillared bodies having a length and
10 thickness greater than those of the first pillared bodies, and includes a cylindrical sieve 10, drive means 20, pillared body supply means 30, clogging removing means 40, and descaling means 50.

[0009]

The cylindrical sieve 10 is a cylindrical body in which hexagonal holes H_1 (refer
15 to FIG. 3) are formed on a circumferential face 11. Note that FIG. 1 shows enlarged holes H_1 .

A material of the cylindrical sieve 10 is not particularly limited, and metal or a resin is possible.

In addition, in the cylindrical sieve 10 according to the present embodiment, a
20 gear wheel 12 that receives a driving force of the drive means 20 is provided in the circumferential face 11.

[0010]

When each first pillared bodies is a pillared body of which a first end face and a second end face are parallel with each other, the first pillared bodies and the second
25 pillared bodies may be separated using the cylindrical sieve 10 formed with the holes H_1

satisfying the following (I) and (II).

(I) When a direction along the opening face of the sieve is set to a Y direction, a direction along an opening face of the sieve and vertical to the Y direction is set to an X direction, and a direction vertical to both of the X direction and the Y direction is set to a Z direction, and a virtual rotation axis A that penetrates the center of gravity of the first pillared body and is parallel with the first end face and the second end face of the first pillared body is disposed inside a hole so as to be along the X-Y plane, and the first pillared body is rotated around the virtual rotation axis A, each hole is a hole having a shape in which the first pillared body can rotate 360° without coming into contact with the sieve, regardless of the direction of the virtual rotation axis A within the X-Y plane.

(II) As shown in FIG. 4, when an area formed by projecting a first pillared body C_1 obtained after 360° rotation of the body around the virtual rotation axis A on the X-Y plane that includes the virtual rotation axis A is set to a first pillared body passing area G , and the interval of edges of the hole H_1 that face each other in the direction of the virtual rotation axis A interposing the first pillared body passing area G is set to D , the hole is a hole of which the minimum value of D is less than the length and the thickness of each second pillared body.

Note that the fact that the first end face and the second end face of the first pillared body are parallel with each other means that an angle formed by the first end face and the second end face is not limited to 180° , and includes $180^\circ \pm 5^\circ$.

[0011]

When the first pillared body is not a pillared body of which the first end face and the second end face are not parallel with each other, the first pillared bodies and the second pillared bodies may be separated using the cylindrical sieve 10 having holes H_1 formed therein satisfying the following (III) and (IV).

(III) When one direction along an opening face of the sieve is set to the Y direction, a direction that is along the opening face of the sieve and vertical to the Y direction is set to the X direction, and a direction vertical to both of the X direction and the Y direction is set to the Z direction, and a virtual rotation axis A that penetrates the center of gravity of the first pillared body and is vertical to the longest portion on a side face of the first pillared body is disposed inside a hole so as to be along the X-Y plane, and the first pillared body is rotated around the virtual rotation axis A, each hole is a hole having a shape in which the first pillared body can rotate 360° without coming into contact with the sieve, regardless of the direction of the virtual rotation axis A within the X-Y plane.

(IV) When an area formed by projecting a first pillared body obtained after 360° rotation of the body around the virtual rotation axis A on the X-Y plane that includes the virtual rotation axis A is set to a first pillared body passing area, and the interval of edges of the hole that face each other interposing the first pillared body passing area is set to D, the hole is a hole of which the minimum value of D is less than the length and the thickness of each second pillared body.

[0012]

The hole H_1 is preferably a hexagonal hole that satisfies all of the following conditions (a) to (d).

(a) Pairs of sides facing each other (a side S_1 and a side S_2 , a side S_3 and a side S_4 , and a side S_5 and a side S_6) of the hole H_1 are parallel with each other and have the same length.

(b) The distance W between any side S_1 of the hole H_1 and a side S_2 that is parallel therewith is greater than a thickness D_{C1} and a length L_{C1} of the first pillared body C_1 (refer to FIGS. 6 and 7). In addition, the distance W is smaller than a thickness

D_{C2} of a second pillared body C_2 (refer to FIG. 8).

(c) When the direction of W is set to the X direction, the direction parallel with the side S_1 is set to the Y direction, and the direction vertical to the X and Y directions is set to the Z direction, a length L_A of the side S_1 and a maximum length L_B of the hexagon in the Y direction are lengths obtained by rotating an axis Q of the first pillared body C_1 so as to be along the Y - Z plane as shown in FIGS. 11, 12, 13, and 14 when the first pillared body C_1 is inserted into the hole H_1 as shown in FIGS. 9 and 10 so that the direction of the axis Q is parallel with the Z direction and a rotation axis P is provided at the center of the direction of the axis Q .

Note that FIGS. 11 and 12 show states in which the first pillared body C_1 of FIGS. 9 and 10 is rotated in an inclined manner, and FIGS. 13 and 14 show states in which the first pillared body C_1 of FIGS. 9 and 10 is rotated by 90° .

(d) L_A and L_B are set to be lengths that cause the second pillared body C_2 not to penetrate through the hole H_1 when the second pillared body C_2 is disposed on the hole H_1 so that the direction of the axis Q is along the X direction. As shown in FIG. 15, when a thickness D_{C2} of the second pillared body C_2 is less than L_A and a length L_{C2} of the second pillared body C_2 is longer than W , the second pillared body C_2 cannot penetrate through the hole H_1 . In addition, as shown in FIG. 16, when the thickness D_{C2} of the second pillared body C_2 is equal to or greater than L_A and the length L_{C2} of the second pillared body C_2 is shorter than W , both end portions of the second pillared body C_2 are caught on the fringe of the hole H_1 by L_A and L_B , and thus, the second pillared body C_2 cannot penetrate therethrough.

When at least one condition of the above-described (a) to (d) is not satisfied, separation of the first pillared bodies C_1 from the second pillared bodies C_2 is difficult.

In addition, in the present embodiment, the hole H_1 is formed so that the side S_1

is along the circumferential direction of the cylindrical sieve 10.

[0013]

The drive means 20 rotates the cylindrical sieve 10, generally using a motor as a driving source. The driving force of the drive means 20 is transmitted to the cylindrical
5 sieve 10 through a gear wheel 21.

The pillared body supply means 30 supplies two kinds of pillared bodies to the inner circumference face side of the cylindrical sieve 10 from a tank 31. The pillared body supply means 30 according to the present embodiment supplies the two kinds of pillared bodies from the tank 31 to the cylindrical sieve 10 using a quantitative feeder 32.

10 The clogging removing means 40 includes a plurality of disks 41 that can be rotated, are arranged in parallel with the rotation direction of the cylindrical sieve 10, and provided on an axis 42 so that the circumferential faces of the disks come into contact with the cylindrical sieve 10.

In the present embodiment, the clogging removing means 40 is provided so as to
15 come into contact with the upper portion of the cylindrical sieve 10. Note that FIG. 1 shows the disks 41 in an enlarged manner. A material of the disks 41 is not particularly limited, but may be metal, or a resin and rubber.

The descaling means 50 is a brush that comes into contact with the inner circumferential face of the cylindrical sieve 10. In the present embodiment, the
20 descaling means 50 comes into contact with a portion on the inner circumferential face of the cylindrical sieve 10 that moves so as to move upward during rotation.

[0014]

<Pillared Body Separation Method>

A method for separating the first pillared bodies from the second pillared bodies
25 having a length and a thickness greater than those of the first pillared bodies using the

pillared body separation device 1 will be described.

In the pillared body separation device of the present embodiment, first, the two kinds of pillared bodies are supplied to the inner circumferential face side of the cylindrical sieve 10 using the pillared body supply means 30, and the drive means 20 is caused to drive so as to rotate the cylindrical sieve 10 via the gear wheels 21 and 12.

Accordingly, the two kinds of pillared bodies are sieved in the lower portion of the inner circumferential face of the rotating cylindrical sieve 10, causing the first pillared bodies to selectively penetrate through the holes H_1 . The first pillared bodies that have

penetrated through the holes H_1 are received and collected in, for example, a container,

and the second pillared bodies that have not penetrated through the holes H_1 are taken out and then collected after the rotation of the cylindrical sieve 10 is stopped. Alternatively,

the second pillared bodies may be eliminated and collected continuously from the opening hole on the opposite side of the pillared body supply side of the cylindrical sieve 10 without stopping the rotation of the cylindrical sieve 10. The entire pillared body

separation device is inclined approximately 0.1 to 20° with the pillared body supply side becomes higher than the other side, promoting the elimination of the second pillared body.

When the two kinds of pillared bodies are sieved by rotating the cylindrical sieve 10, there are cases in which the holes H_1 are clogged with the pillared bodies, in the present embodiment, however, clogging is resolved in such a way that the rotating disks 41 of the clogging removing means 40 cram the pillared bodies causing the clogging into the inner circumferential face side of the cylindrical sieve 10 so as to return to the inside.

In addition, when the two kinds of pillared bodies are sieved by rotating the cylindrical sieve 10, there are cases in which scale generated from at least one of the first pillared bodies and the second pillared bodies adheres to the inner circumferential face of

the cylindrical sieve 10, in the present embodiment, however, the descaling means 50 that includes the brush scratches and removes the scale adhering to the inner circumferential face of the cylindrical sieve 10. In addition, scale may be removed by appropriately tapping the cylindrical sieve 10 using a hammer.

5 [0015]

As the two kinds of pillared bodies applied to the pillared body separation device described above, columnar bodies, square prism bodies, triangular prism bodies, pentagonal prism bodies, hexagonal prism bodies, and the like are exemplified. Among these, ones that are used mostly are columnar bodies.

10 As two kinds of columnar bodies, for example, a columnar body as a solid catalyst and a columnar body for dilution (for example, a ceramics columnar body, a metal columnar body, and the like) are exemplified.

Note that, in the present invention, a columnar body also includes a cylindrical body such as a spring.

15 The first pillared body is preferably to have the ratio of the length to the diameter is 0.2 to 5.

The ratio of the diameter of the second pillared body to that of the first pillared body (the diameter of the second pillared body / the diameter of the first pillared body) is preferably 1.05 to 6.00.

20 The ratio of the length of the second pillared body to the diameter of the first pillared body (the length of the second pillared body / the diameter of the first pillared body) is preferably 1.05 to 6.00.

In the present invention, when the pillared body is a columnar body, the thickness of the pillared body is the diameter of the columnar body. When the pillared
25 body is a prismatic body, the thickness of the pillared body is the diameter of the

circumscribed circle on a face having the largest area among cross-sections that are vertical to the longitudinal direction of the prismatic body.

[0016]

In the present embodiment, since the shape of the holes H_1 of the sieve is
5 hexagon satisfying all of the conditions (a) to (d) described above, two kinds of pillared bodies having different lengths and thicknesses, particularly, two kinds of columnar bodies of which differences between the lengths and the diameters are subtle can be reliably separated.

In addition, in the present embodiment, since the sieve is the rotating cylindrical
10 sieve 10, continuous separation is possible with ease, and further, the pillared body separation device 1 can be easily in a compact size.

[0017]

Note that the present invention is not limited to the above embodiment. For example, the pillared body supply means may supply the two kinds of pillared bodies to
15 the cylindrical sieve by causing the pillared bodies to fall from the tank under their own weight when a valve attached to a lower portion of the tank is open. For the clogging removing means, a plurality of protruding rods may be arranged in a comb shape so as to correspond to the holes.

In addition, the pillared body separation device of the present invention may not
20 be provided with the pillared body supply means, the clogging removing means, and the descaling means. When the pillared body supply means is not provided, an operator may supply the two kinds of pillared bodies to the cylindrical sieve, when the clogging removing means is not provided, an operator may remove clogging after stopping the device first, and when the descaling means is not provided, an operator may remove scale
25 after stopping the device first.

In addition, it is not necessary to provide one pillared body separation device 1, and two or more devices may be connected in series.

In addition, it is not necessary for the sieve to be a cylindrical shape, and a plate shape may be possible. When the sieve has a plate shape, the sieve is preferably tilted
5 and then vibrated.

[0018]

The shape of the holes formed in the sieve is not limited to be hexagon as described above, and may be holes H_2 to H_{13} as shown in FIG. 17.

Note that, when the holes are not hexagonal shape, the Y directions are not
10 limited to be parallel to the longest direction of the holes, and a first side S_1 to a fourth side S_4 when the holes are not hexagonal shape are not related to a first side S_1 to a fourth side S_4 when the holes are hexagonal shape.

The hole H_2 has a first side S_1 and a second side S_2 both of which are linear, an interval of which becomes narrow as they approach a third side S_3 .

15 The hole H_3 has a rectangular shape and corners bending by 90° .

The hole H_4 has an octagonal shape.

The hole H_5 has a pentagonal shape, and a first side S_1 and a second side S_2 both of which are linear and parallel with each other.

The hole H_6 has an oblong shape, and a first side S_1 and a second side S_2 both of
20 which are linear and parallel with each other.

The hole H_7 has a rectangular shape, but corners in a curved shape.

The hole H_8 has a first side S_1 and a second side S_2 both of which are linear and parallel with each other, a third side S_3 in a curved shape, and a fourth side S_4 in a linear shape. Note that, in the case of the hole is not a hexagonal shape in the present

25 invention, the boundary between the first side S_1 and the third side S_3 or the fourth side

S_4 , and the boundary between the second side S_2 and the third side S_3 or the fourth side S_4 are portions in which the directions of the sides change on the X-Y plane.

The hole H_9 has a first side S_1 and a second side S_2 both of which are wave shapes, and the interval between the first side S_1 and the second side S_2 is fixed.

5 The hole H_{10} has a first side S_1 and a second side S_2 both of which are zigzag shapes, and the interval between the first side S_1 and the second side S_2 periodically changes.

The hole H_{11} has a first side S_1 and a second side S_2 both of which are zigzag shapes, and the interval between the first side S_1 and the second side S_2 is fixed.

10 The hole H_{12} has a pentagonal shape, and the interval between a first side S_1 and a second side S_2 thereof becomes narrower as they approach a third side S_3 thereof.

The hole H_{13} has a hexagonal shape, and a first side S_1 and a second side S_2 both of which are slightly inflated outward so as to form curbed shapes.

The holes H_1 to H_{13} are longer in the Y direction than in the X direction. If the
15 holes H_1 to H_{13} are longer in the Y direction than in the X direction, two kinds of pillared bodies of which lengths and thicknesses are slightly different can be more easily separated.

In addition, the hole in an oblong shape is preferable in terms of having high separability in the same manner as the hexagonal holes. However, the oblong shape
20 does not necessarily have a first side S_1 and a second side S_2 both of which are linear and parallel with each other unlike the hole H_6 , and for example, an elliptical shape is also included in the oblong shape.

[Example]

[0019]

25 (Example 1)

In the pillared body separation device 1 shown in FIGS. 1 and 2, catalyst columnar bodies (having a diameter of 5 mm and a length of 5 mm) and stainless-made springs as columnar bodies (having a diameter (outer diameter) of 6 mm and a length of 6 mm) were separated using the cylindrical sieve 10 in a hexagonal shape having the

5 holes H_1 shown in FIG. 3 of which W is 5.5 mm, L_A is 4.5 mm, and L_B is 13.5 mm.

Note that the holes H_1 of the used cylindrical sieve 10 which have the dimensions as described above satisfy the conditions (a) to (d). In other words:

- (a) Each hole H_1 has pairs of sides (a side S_1 and a side S_2 , a side S_3 and a side S_4 , and a side S_5 and a side S_6) facing each other which are parallel with each other and
- 10 have the same length;
- (b) The distance W between the side S_1 and the side S_2 of the hole H_1 is greater than the diameter and the length of each catalyst columnar body and smaller than the diameter of each spring;
- (c) When the catalyst columnar body is inserted into the hole H_1 so that the axis
- 15 direction of the body is parallel with the Z direction and the rotation axis P is provided at the center of the axis direction, the length L_A of the side S_1 and the maximum length L_B of the hexagon in the Y direction are lengths in which an axis Q of the catalyst columnar body can rotate so as to be along the Y - Z plane; and
- (d) L_A and L_B are lengths in which each spring cannot penetrate through the hole
- 20 H_1 when the spring is disposed on the hole H_1 so that the axis direction thereof is along the X direction.

The holes H_1 of the present example are arranged in series in both of the X direction and the Y direction as shown in FIG. 18.

The separation of the columnar bodies was performed specifically in such a way

25 that two kinds of columnar bodies were supplied to the inner circumferential face side of

the cylindrical sieve 10 using the pillared body supply means 30 while the cylindrical sieve 10 was rotated using the drive means 20, then the springs remained in the cylindrical sieve 10, and the catalyst columnar bodies penetrated through the hole H₁.

In addition, the mass of catalyst columnar bodies that penetrated through the cylindrical sieve out of the catalyst columnar bodies supplied to the cylindrical sieve is set to a and the mass of catalyst columnar bodies that remained in the cylindrical sieve is set to b, the following formulas are formed:

(The ratio A of the catalyst columnar bodies that penetrated through the cylindrical sieve) = $a / (a+b) \times 100$ [mass%],

(The ratio B of the catalyst columnar bodies that remained in the cylindrical sieve) = $b / (a+b) \times 100$ [mass%], and

the mass of springs that penetrated through the cylindrical sieve out of the springs supplied to the cylindrical sieve is set to c, and the mass of springs that remained in the cylindrical sieve is set to d, the following formulas are formed:

(The ratio C of the springs that penetrated through the cylindrical sieve) = $c / (c+d) \times 100$ [mass%],

(The ratio D of the springs that remained in the cylindrical sieve) = $d / (c+d) \times 100$ [mass%], and

separability was evaluated using a separability index E as follows:

(Separability index E) = (the ratio A of the catalyst columnar bodies that penetrated through the cylindrical sieve) / 100 $\times$ (the ratio D of the springs that remained in the cylindrical sieve) / 100.

Herein, since the separability index E is the result obtained by multiplying the amount of penetrated objects (catalyst columnar bodies) which were desired to cause

penetration (favorable as the amount becomes closer to 100%) by the amount of remaining objects (springs) which were desired to remain (favorable as the amount becomes closer to 100%), the index is favorable as it becomes closer to 1. If the index is equal to or greater than 0.90, the separability is determined to be favorable. The separability equal to or more than 0.95 is more favorable.

In addition, the ratio (%) of the number of clogged holes to the number of all holds of the cylindrical sieve was also measured. The results are shown in Table 1.

[0020]

(Example 2)

Catalyst columnar bodies (having the diameter of 5 mm and the length of 5 mm) and stainless-made springs (having the diameter (outer diameter) of 6 mm and the length of 6 mm) were separated by forming the same holes as those in Example 1 and using a plate-like sieve inclined by an angle of 4°. During the separation, the sieve was vibrated using a vibrator. Then, separability was evaluated in the same manner as in Example 1. The results are shown in Table 1.

Note that, in the present example, since a plate-like sieve was used, the separability index E was obtained by replacing “remained in the cylindrical sieve” with “remained on the sieve”.

[0021]

(Example 3)

Two kinds of columnar objects were separated in the same manner as in Example 1 except that holes of a cylindrical sieve were set to have the type of the oblong shaped hole H_6 having a substantially rectangular shape (L_A : 5 mm and L_B : 28mm) shown in FIG. 17 and the arrangement of the holes in the X direction is set to be zigzag and the arrangement thereof in the Y direction is in series as shown in FIG. 19. In

addition, separability was evaluated in the same manner as in Example 1. The results are shown in Table 1.

[0022]

(Comparative Example 1)

- 5 Two kinds of columnar objects were separated in the same manner as in Example 1 except that holes of a cylindrical sieve were set to have the type of holes H_{20} in a true circle shape (having an aperture diameter of 5 mm) and the arrangement of the holes in the X direction and in the Y direction was in series as shown in FIG. 20. In addition, separability was evaluated in the same manner as in Example 1. The results
- 10 are shown in Table 1.

[0023]

[Table 1]

	Unit	Example 1		Example 2		Example 3		Comparative Example 1	
		Catalyst Columnar Body	Spring	Catalyst Columnar Body	Spring	Catalyst Columnar Body	Spring	Catalyst Columnar Body	Spring
Ratio of penetrating sieve	Mass%	99.9	0.2	98.8	0.2	90.8	0.0	8.4	0.0
Ratio of remaining in or on sieve	Mass%	0.1	99.8	1.2	99.8	9.2	100.0	91.6	100.0
Separability index E	-	0.997		0.986		0.908		0.084	
Ratio of clogged holes	%	0.4		2.9		6.9		1.6	

[0024]

In Examples 1, 2, and 3, the separability index E was 0.997, 0.986, and 0.908, which was close to 1. In other words, the two kinds of pillared bodies (catalyst columnar bodies and springs) having subtle differences in lengths and diameters were
5 excellent in separability.

In Comparative Example 1 in which the two kinds of columnar bodies were separated using the sieve with circular holes, the separability index E was 0.084 which is lower than those in Examples, and therefore, separability of the two kinds of columnar bodies having subtle differences in lengths and diameters was insufficient.

10 While preferred embodiments of the invention have been described and illustrated above, it should be understood that these are exemplary of the invention and are not to be considered as limiting. Additions, omissions, substitutions, and other modifications can be made without departing from the spirit or scope of the present invention. Accordingly, the invention is not to be considered as being limited by the
15 foregoing description, and is only limited by the scope of the appended claims.

[0025]

1: pillared body separation device

10: cylindrical sieve

11: circumferential face

20 12: gear wheel

20: drive means

21: gear wheel

30: pillared body supply means

31: tank

25 32: quantitative feeder

40: clogging removing means

41: disks

42: axis

50: descaling means

5 H_1 to H_{13} : holes

What is claimed is:

1. A pillared body separation method for separating first pillared bodies each of which has a first end face and a second end face parallel with each other from second pillared
5 bodies each of which has a length and a thickness greater than those of the first pillared body by using a sieve that has holes formed therein satisfying the following conditions

(I) and (II):

(I) when a direction along an opening face of the sieve is set to a Y direction, a direction along an opening face of the sieve and vertical to the Y direction is set to an X
10 direction, and a direction vertical to both of the X direction and the Y direction is set to a Z direction, and a virtual rotation axis A that penetrates the center of gravity of the first pillared body and is parallel with the first end face and the second end face of the first pillared body is disposed inside a hole so as to be along the X-Y plane, and the first
15 pillared body is rotated around the virtual rotation axis A, each hole is a hole having a shape in which the first pillared body can rotate 360° without coming into contact with the sieve, regardless of the direction of the virtual rotation axis A within the X-Y plane; and

(II) when an area formed by projecting a first pillared body obtained after 360° rotation of the body around the virtual rotation axis A on the X-Y plane that includes the
20 virtual rotation axis A is set to a first pillared body passing area, and the interval of edges of the hole that face each other in the direction of the virtual rotation axis A interposing the first pillared body passing area is set to D, the hole is a hole of which the minimum value of D is less than the length and the thickness of each second pillared body.

25 2. A pillared body separation method for separating first pillared bodies each of which

has a first end face and a second end face not parallel with each other and second pillared bodies each of which has a length and a thickness greater than those of each first pillared body using a sieve that has holes formed therein satisfying the following conditions (III) and (IV):

- 5 (III) when a direction along an opening face of the sieve is set to a Y direction, a direction that is along an opening face of the sieve and vertical to the Y direction is set to an X direction, and a direction vertical to both of the X direction and the Y direction is set to a Z direction, and a virtual rotation axis A that penetrates the center of gravity of the first pillared body and is vertical to the longest straight line of the distance between
 - 10 the first end face and the second end face on a side face of the first pillared body is disposed inside a hole so as to be along the X-Y plane, and the first pillared body is rotated around the virtual rotation axis A, each hole is a hole having a shape in which the first pillared body can rotate 360° without coming into contact with the sieve, regardless of the direction of the virtual rotation axis A within the X-Y plane; and
- 15 (IV) when an area formed by projecting a first pillared body obtained after 360° rotation of the body around the virtual rotation axis A on the X-Y plane that includes the virtual rotation axis A is set to a first pillared body passing area, and the interval of edges of the hole that face each other interposing the first pillared body passing area in the direction of the virtual rotation axis A is set to D, the hole is a hole of which the
 - 20 minimum value of D is less than the length and the thickness of each second pillared body.

3. The pillared body separation method according to claim 1, wherein the holes have a hexagonal shape.

4. The pillared body separation method according to claim 2, wherein the holes have a hexagonal shape.

5. The pillared body separation method according to claim 1, wherein the holes have an oblong shape.

6. The pillared body separation method according to claim 2, wherein the holes have an oblong shape.

7. The pillared body separation method according to claim 3 or 4, wherein the holes satisfy all of the following conditions (a) to (d):

(a) each hole has pairs of sides facing each other which are parallel with each other and have the same length;

(b) the distance W between any side S_1 of the hole and a side S_2 that is parallel with the side S_1 is greater than the diameter and the length of each first pillared body and smaller than the diameter of each second pillared body;

(c) when the direction of W is set to the X direction, the direction parallel with the side S_1 is set to the Y direction, and the direction vertical to both of the X direction and the Y direction is set to the Z direction, and the first pillared body is inserted into the hole so that the axis direction of the body is parallel with the Z direction and a rotation axis is provided at the center of the axis direction, a length L_A of the side S_1 and the maximum length L_B of the hexagon in the Y direction are lengths in which an axis of the first pillared body can rotate so as to be along the Y - Z plane; and

(d) L_A and L_B are lengths in which each second pillared body cannot penetrate through the hole when the body is disposed on the hole so that the axis direction thereof

is along the X direction.

8. The pillared body separation method according to claim 7, wherein the first pillared body and the second pillared body are respectively columnar bodies.

5

9. The pillared body separation method according to any one of claims 1 to 8, wherein the sieve is a cylindrical sieve, the first pillared body and the second pillared body are supplied to an inner circumferential face side of the cylindrical sieve, and the cylindrical sieve is rotated.

10

10. The pillared body separation method according to claim 9, wherein scale that is generated from at least one of the first pillared bodies and the second pillared bodies and adheres to the inner circumferential face of the cylindrical sieve is removed.

15 11. The pillared body separation method according to claim 10, wherein the scale is removed by bringing a brush into contact with the inner circumferential face of the cylindrical sieve.

12. The pillared body separation method according to claim 10, wherein the scale is
20 removed by tapping the cylindrical sieve with a hammer.

13. A pillared body separation device that includes a sieve having holes that are formed therein satisfying the following conditions (I) and (II) and separates first pillared bodies each of which has a first end face and a second end face parallel with each other from
25 second pillared bodies each of which has a length and a thickness greater than those of

each first pillared body, the conditions are:

(I) when a direction along the opening face of the sieve is set to a Y direction, a direction along an opening face of the sieve and vertical to the Y direction is set to an X direction, and a direction vertical to both of the X direction and the Y direction is set to a Z direction, and a virtual rotation axis A that penetrates the center of gravity of the first pillared body and is parallel with the first end face and the second end face of the first pillared body is disposed inside a hole so as to be along the X-Y plane, and the first pillared body is rotated around the virtual rotation axis A, each hole is a hole having a shape in which the first pillared body can rotate 360° without coming into contact with the sieve, regardless of the direction of the virtual rotation axis A within the X-Y plane; and

(II) when an area formed by projecting a first pillared body obtained after 360° rotation of the body around the virtual rotation axis A on the X-Y plane that includes the virtual rotation axis A is set to a first pillared body passing area, and the interval of edges of the hole that face each other in the direction of the virtual rotation axis A interposing the first pillared body passing area is set to D, the hole is a hole of which the minimum value of D is less than the length and the thickness of each second pillared body.

14. A pillared body separation device that includes a sieve having holes that are formed therein satisfying the following conditions (III) and (IV) and separates first pillared bodies each of which has a first end face and a second end face not parallel with each other from second pillared bodies each of which has a length and a thickness greater than those of each first pillared body, the conditions are:

(III) when one direction along an opening face of the sieve is set to a Y direction, a direction that is along the opening face of the sieve and vertical to the Y direction is set

to an X direction, and a direction vertical to both of the X direction and the Y direction is set to a Z direction, and a virtual rotation axis A that penetrates the center of gravity of the first pillared body and is vertical to the longest straight line of the distance between the first end face and the second end face on a side face of the first pillared body is
 5 disposed inside a hole so as to be along the X-Y plane, and the first pillared body is rotated around the virtual rotation axis A, each hole is a hole having a shape in which the first pillared body can rotate 360° without coming into contact with the sieve, regardless of the direction of the virtual rotation axis A within the X-Y plane; and

(IV) when an area formed by projecting a first pillared body obtained after 360°
 10 rotation of the body around the virtual rotation axis A on the X-Y plane that includes the virtual rotation axis A is set to a first pillared body passing area, and the interval of edges of the hole that face each other interposing the first pillared body passing area in the direction of the virtual rotation axis A is set to D, the hole is a hole of which the minimum value of D is less than the length and the thickness of each second pillared
 15 body.

15. The pillared body separation device according to claim 13 or 14, wherein holes have a hexagonal shape, satisfying all of the following conditions (a) to (d):

(a) each hole has pairs of sides facing each other which are parallel with each
 20 other and have the same length;

(b) the distance W between any side S_1 of the hole and a side S_2 that is parallel with the side S_1 is greater than the diameter and the length of each first pillared body and smaller than the diameter of each second pillared body;

(c) when the direction of W is set to the X direction, the direction parallel with
 25 the side S_1 is set to the Y direction, and the direction vertical to both of the X direction

and the Y direction is set to the Z direction, and the first pillared body is inserted into the hole so that the axis direction of the body is parallel with the Z direction and a rotation axis is provided at the center of the axis direction, a length L_A of the side S_1 and the maximum length L_B of the hexagon in the Y direction are lengths in which an axis of the

5 first pillared body can rotate so as to be along the Y-Z plane; and

(d) L_A and L_B are lengths in which each second pillared body cannot penetrate through the hole when the body is disposed on the hole so that the axis direction thereof is along the X direction.