

DESCRIPTION**TITLE : Tubular reactor with fixed bed**

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The invention relates to a tubular reactor comprising: a casing, extending along a main axis ; and an insert placed in said casing, the casing and the insert delimiting an intermediate space, able to contain a bed of catalytic powder; the insert being configured for allowing a gas flow between said insert and the intermediate space.

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The invention specifically relates to the field of catalytic exchange reactors involving a solid catalyst, especially a powder catalyst. As an example, such a reactor is disclosed in document FR3103714, in the name of one of the Applicants.

However, such a reactor involves implementation constraints, in particular due to the complex shape of the insert.

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The invention aims to simplify the manufacturing of the reactor. To this end, the invention relates to a tubular reactor of the aforementioned type, wherein the insert comprises at least a first and a second tubes, extending respectively along a first and along a second secondary axes ; and in that said tubular reactor also comprises a support placed in the intermediate space and fixed to each of the first and second tubes, the support maintaining said first and second tubes at a distance from each other perpendicularly to the main axis, so that each of the first and second secondary axes extends parallel to the main axis.

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According to embodiments, the tubular reactor may include one or more of the following features, considered alone or in any technically possible combination:

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- the support comprises a first maintaining element,
- the first maintaining element comprises a first and a second hooks, fit together respectively with the first and with the second tubes;
- the support also comprises a mast extending in the casing along the main axis; the first maintaining element extending radially around the mast;
- the first maintaining element has an openwork shape, allowing a fluid flow between a first and a second axial ends of the casing, the support being received in said casing;
- the support also comprises a second maintaining element fixed to the first and to the second tubes;
- each of the first and second tubes has a substantially circular section;
- at least one of the first and second tubes comprises a plurality of gas-permeable openings, substantially aligned parallel to the first or to the second secondary axis;

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- the support comprises a device for the angular positioning of the at least one of the first and second tubes, so that the plurality of gas-permeable openings is placed substantially opposite the main axis relative to the first or to the second secondary axis;

- the tubular reactor comprises a plurality of first tubes and a plurality of second tubes, the reactor also comprising: a first end compartment, opening on a first end of the first tubes ; and a second end compartment, opening on a second end of the second tubes.

The invention also relates to a method for manufacturing a tubular reactor as described above, comprising the following steps: making the first and second tubes ; and making the support ; then fixing the support to the first and to the second tubes ; then introducing the support and the first and second tubes in the casing, so as to form the intermediate space.

The invention will be easier to understand in view of the following description, provided solely as an example, and with reference to the appended drawings, wherein:

[Fig. 1] Figure 1 is a longitudinal section view of a tubular reactor according to an embodiment of the invention;

[Fig. 2] Figure 2 is a transversal section view of the tubular reactor of Figure 1 ; and

[Fig. 3] Figure 3 is a sectional view of elements of the tubular reactor of Figures 1 and 2.

Figures 1 and 2 show a tubular reactor 10 according to an embodiment of the invention.

More precisely, the reactor 10 is a tubular exchange reactor with a fixed bed of catalytic powder.

The reactor 10 comprises: a casing 12; an insert 14; and a support 15. In the shown embodiment, the reactor 10 also comprises: a bed 16 of catalytic powder ; and a first 17 and a second 18 end compartments.

The casing 12 has a tubular shape and extends along a main axis 20. More precisely, the casing comprises a tubular main body 19, having an elongated shape between a first 21 and a second 22 ends along the main axis 20.

In the shown embodiment, the main body 19 comprises an inner wall 23 of cylindrical shape along the main axis 20 and of substantially circular section.

The casing 12 also comprises a first 24 and a second 26 transversal walls, placed respectively at the first 21 and at the second 22 ends of the main body 19 of said casing 12. Each transversal wall 24, 26 is substantially planar and perpendicular to the main axis 20.

According to another embodiment (not shown), the casing does not comprise the first transversal wall 24.

The insert 14 is placed in the casing 12. More precisely, the casing 12 and the insert 14 delimit an intermediate space 28, contained in said casing 12 between the main body 19 and the insert 14. The intermediate space 28 is axially delimited by the first 24 and second 26 transversal walls of the casing 12.

5 The insert 14 comprises at least a first 30 and a second 32 tubes. More precisely, in the shown embodiment, the insert 14 comprises tubes, that is two first tubes 30, 34 and two second tubes 32, 36. In an unshown alternative embodiment, as specified below, the insert comprises a number of first and second tubes superior to two.

10 Each of the tubes 30, 32, 34, 36 extends substantially rectilinearly along a secondary axis, respectively 40, 42, 44, 46, each of said secondary axes being parallel to the main axis 20.

In the shown embodiment, each of the tubes 30, 32, 34, 36 has a substantially circular section. However, other section shapes may be used for the tubes, such as polygonal sections.

15 The insert 14 is configured for allowing a gas flow being said insert 14 and the intermediate space 28. In the shown embodiment, each of the tubes 30, 32, 34, 36 comprises a plurality of openings 48 distributed along a length of said tube, parallel to the corresponding secondary axis 40, 42, 44, 46. Preferably, the openings 48 are distributed along one or several generatrices of the tube 30, 32, 34, 36. In the shown embodiment, the openings 48 are distributed along a single generatrix of each tube 30, 32, 34, 36.

Only a few of the openings 48 of the first tubes 30, 34 are shown on Figure 1. However, the openings 48 are preferably distributed along more of 50% of a length of the corresponding tube, more preferably along more of 75% of said length.

25 As shown on Figure 1, each of the first tubes 30, 34 extends between an open first end 50, close to the first end 21 of the casing 12, and a closed second end 52, close to the second end 22 of the casing 12.

Besides, each of the second tubes 32, 36 extends between a closed first end, close to the first end 21 of the casing 12, and an open second end 54, close to the second end 22 of the casing 12.

30 As shown on Figure 1, the open first end 50 of each of the first tubes 30, 34 axially protrudes relative to the casing 12. More precisely, the open first end 50 of each of the first tubes 30, 34 is inserted in an opening 56 of the first transversal wall 24 of the casing.

35 Similarly, the open second end 54 of each of the second tubes 32, 36 axially protrudes relative to the casing 12. More precisely, the open second end 54 of each of the second tubes 32, 36 is inserted in an opening of the second transversal wall 26 of the casing.

Preferably, as in the shown embodiment, the insert 14 comprises a same number of first 30, 34 and of second 32, 36 tubes; and said first 30, 34 and second 32, 36 tubes are arranged alternately around the main axis 20 of the casing. In an alternative embodiment, the insert comprises three first tubes and three second tubes, arranged alternately around the main axis of the casing.

The support 15 is placed in the intermediate space 28, between the first 24 and second 26 transversal walls of the casing 12.

As detailed below, the support 15 is fixed to the casing 12 and to each of the first 30, 34 and second 32, 36 tubes so that each of the secondary axes 40, 42, 44, 46 extends parallel to the main axis 20.

Moreover, in the shown embodiment, the support maintains the tubes 30, 32, 34, 36 at a distance from each other perpendicular to the main axis 20.

Preferably, the support 15 comprises at least a maintaining element 62, 64. In the shown embodiment, the support 15 comprises a first 62 and a second 64 maintaining elements.

In the shown embodiment, the first 62 and second 64 maintaining elements are arranged close, respectively, to the first 21 and to the second 22 ends of the casing 12. In an unshown embodiment, the support 15 comprises a number of maintaining elements superior or equal to three, said maintaining elements being distributed along a length of the casing 12.

The first maintaining element 62 and the first tubes 30, 34 are shown in cross-sectional view on Figure 3, perpendicular to the main axis 20.

Each maintaining element 62, 64 is fixed to each of the tubes 30, 32, 34, 36. More precisely, in the shown embodiment, each maintaining element 62, 64 comprises at least a first 71 and a second 72 hooks. Each hook 71, 72 is fit together with, respectively, a first 30, 34 or a second 32, 36 tube.

Preferably, the maintaining element 62, 64 is manufactured from a material allowing an elastic deformation of each hook 71, 72 during the fitting on the corresponding tube 30, 32, 34, 36.

In the shown embodiment, an opening 73 of each hook 71, 72 is substantially oriented in a tangential direction relative to the main axis 20. In an unshown embodiment, an opening of each hook is oriented in a radial direction relative to the main axis 20.

In the shown embodiment, each hook 71, 72 comprises an end finger 74 in contact with the inner wall 23 of the main body 19 of the casing 12. The end finger 74 especially allow to maintain a minimal distance between each tube 30, 32, 34, 36 and the inner wall 23.

In unshown embodiments, the at least one maintaining element comprises rings able to receive the corresponding tubes 30, 32, 34, 36, or a plate comprising openings able to receive said tubes. However, preferably, a surface of each maintaining element 62, 64, perpendicular to the main axis 20, is inferior to an inner section of the casing 12. In other terms, each maintaining element 62, 64 has an openwork shape, allowing a fluid flow between the first 21 and the second 22 ends of the casing, the support 15 being received in said casing.

In the shown embodiment, the support 15 also comprises a mast 60. The mast 60 extends in the casing 12 parallel to the main axis 20. In the shown embodiment, the mast 60 is aligned with the main axis 20.

More precisely, the mast 60 extends between a first and a second ends, fixed respectively to the first 24 and to the second 26 transversal walls of the casing 12.

In the shown embodiment, the mast 60 is formed by several sections 66, 67, 68, adjacent to each other along the main axis 20.

Each maintaining element 62, 64 is fixed to the mast 60 and extends radially around said mast.

In the shown embodiment, each maintaining element comprises a central opening 70. As shown on Figure 1, the mast 60 is fixed to each maintaining element 62, 64 by insertion in the corresponding central opening 70. More precisely, the ends of two adjacent sections 66, 67, 68 of the mast are fixed to each other level to the central opening 70 of a maintaining element 62, 64.

Preferably, each tube 30, 32, 34, 36 is fixed to the support 15 in a predefined angular position relative to the main axis 20. In said angular position, the plurality of openings 48 of said tube is arranged substantially opposite the main axis 20 relative to the corresponding secondary axis 40, 42, 44, 46. More precisely, said angular position is such that the openings 48 of each tube are oriented toward the inner wall 23 of the main body 19 of the casing 12.

More preferably, the reactor 10 comprises an angular positioning organ 75, 76 for each tube 30, 32, 34, 36.

In the shown embodiment, at least one of the hooks 71, 72 of each maintaining element 62, 64 comprises a peg 75 configured for being inserted into a notch 76 formed in the corresponding tube 30, 32, 34, 36 when said tube is in the angular position described above.

More precisely, in the shown embodiment, each of the first hooks 71 of the first maintaining element 62 comprises a peg 75 as described above, able to be inserted in a notch 76 of one of the first tubes 30, 34 ; and each of the second hooks 72 of the second

maintaining element 64 comprises a similar peg, able to be inserted in a similar notch of one of the second tubes 32, 36.

In the shown embodiment, the bed 16 of catalytic powder is received in the intermediate space 28, radially between the insert 14 and the main body 19 of the casing 12, and axially between the first 24 and second 26 transversal walls. The support 15 is immersed in the catalytic powder.

Preferably, the main axis 20 is arranged substantially vertically ; and a height of the bed 16 of catalytic powder is such that the openings 48 of the tubes 30, 32, 34, 36 are immersed in said bed 16.

Preferably, the openings 48 of the tubes 30, 32, 34, 36 comprise filters 78, said filters being gas-permeable but impervious to solids, so as to avoid the introduction of powder in the tubes 30, 32, 34, 36 through said openings 48. For example, the filters 78 are shaped as covers slipped on the tubes 30, 32, 34, 36. Alternatively, the filters 78 are shaped as filter strips locally applied on the openings 48.

In the shown embodiment, the first 17 and the second 18 end compartments are arranged respectively at the first 21 and at the second 22 ends of the casing 12; the open first end 50 of each first tube 30, 34 opens in the first end compartment 17 ; and the open second end 54 of each second tube 32, 36 opens in the second end compartment 18.

In the shown embodiment, the reactor 10 also comprises: a gas inlet 80, opening on the first end compartment 17 ; and a gas outlet 82, opening on the second end compartment 18.

A method for manufacturing the tubular reactor 10 will now be described.

The first 30, 34 and second 32, 36 tubes may be made from commercially available tubes, by piercing openings 48 along the length of each tube, adding a gas-permeable filter 78 on said openings and cutting the notches 76 at the appropriate locations. The appropriate end 52 of each tube is closed, for example by a plug 84.

In an embodiment, stainless steel tubes are used for manufacturing the first 30, 34 and second 32, 36 tubes. In particular, stainless steel tubes are preferable for manufacturing a reactor intended for catalytic reactions involving dihydrogen (H_2).

The maintaining elements 62, 64 are for example manufactured by molding a thermoplastic material, and are then assembled to the sections 66, 67, 68 of the mast 60 for forming the support 15. Said support 15 is then assembled to each tube 30, 32, 34, 36 by snap-fitting the hooks 71, 72 to said tubes and by inserting each peg 75 in the appropriate notch 76, as described above.

The main body 19 of the casing 12 may be obtained from a commercially available tube. The assembly formed by the tubes 30, 32, 34, 36 and the support 15 is introduced in

said main body 19, then the second transversal wall 26 is fixed to the second end 22 of said main body and to the corresponding end of the mast 60. The open ends 54 of the second tubes 32, 36 are introduced in the corresponding openings of the second transversal wall 26, as described above.

5 Then the main body 19 of the casing 12 is arranged vertically, the second transversal wall 26 being situated at the bottom end. Catalytic powder is then poured in the casing 12 by the first end 21, so as to form the bed 16 of catalytic powder. The openwork shape of the maintaining elements 62, 64 allows the powder to flow along the full height of the main body 19.

10 In the shown embodiment, the first transversal wall 24 is then fixed to the first end 21 of the main body 19 and at the corresponding end of the mast 60. The open end 50 of the first tubes 30, 34 are introduced in the corresponding openings 56 of the first transversal wall 24.

15 The first 17 and second 18 end compartments are then assembled to the first 24 and second 26 transversal walls. Alternatively, said first 17 and second 18 end compartments are made in one piece, respectively with said first 24 and said second 26 transversal wall.

The reactor 10 described above is thus obtained.

A method for implementing the reactor 10 will now be described.

20 A reactive gas, optionally formed as a gas mixture, is introduced in the first end compartment 17 through the gas inlet 80. Through the open first ends 50, said reactive gas is distributed in the first tubes 30, 34 then flows through the openings 48 of said first tubes, to the bed 16 of catalytic powder contained in the intermediate space 28.

25 Then, the reactive gas flows in the bed 16 of catalytic powder, mainly along the inner wall 23 of the main body 19 of the casing 12. During the flowing of the reactive gas, said gas undergoes a chemical reaction on contact with the catalyst(s) of the powder bed 16.

30 The gas flow then reaches the openings 48 of the second tubes 32, 36, adjacent to the first tubes 30, 34. The gas, loaded with the product(s) of the catalytic reaction, then enters said second tubes 32, 36. The gas then enters the second end compartment 18, through the open second ends 54 of said second tubes.

The gas is then evacuated through the gas inlet 82.

Preferably, such a method is implemented for the synthesis of organic compounds, the reactive gas containing at least dihydrogen (H_2) and carbon dioxide (CO_2).

35 The reactor 10 described above is easy to make out of commercially available parts, such as stainless steel tubes. Such a material is advantageously used for making the insert 14, especially due to its resistance to corrosion.

CLAIMS

1. Tubular reactor (10) comprising: a casing (12), extending along a main axis (20) ; and an insert (14) placed in said casing, the casing (12) and the insert (14) delimiting an intermediate space (28), able to contain a bed (16) of catalytic powder; the insert (14) being configured for allowing a gas flow between said insert and the intermediate space (28);

the tubular reactor being characterized in that the insert (14) comprises at least a first (30, 34) and a second (32, 36) tubes, extending respectively along a first (40, 44) and along a second (42, 46) secondary axes ; and in that said tubular reactor also comprises a support (15) placed in the intermediate space (28) and fixed to each of the first (30, 34) and second (32, 36) tubes, the support maintaining said first and second tubes at a distance from each other perpendicularly to the main axis (20), so that each of the first (40, 44) and second (42, 46) secondary axes extends parallel to the main axis (20).

2. Tubular reactor according to claim 1, wherein the support (15) comprises a first maintaining element (62, 64), fit together respectively with the first (30, 34) and with the second (32, 36) tubes, said first maintaining element preferably comprising a first (71) and a second (72) hooks.

3. Tubular reactor according to claim 2, wherein the support (15) also comprises a mast (60) extending in the casing (12) along the main axis, the first maintaining element (62, 64) extending radially around the mast.

4. Tubular reactor according to claim 2 or 3, wherein the first maintaining element (62, 64) has an openwork shape, allowing a fluid flow between a first (21) and a second (22) axial ends of the casing, the support (15) being received in said casing.

5. Tubular reactor according to one of claims 2 to 4, wherein the support (15) also comprises a second maintaining element (62, 64) fixed to the first (30, 34) and to the second (32, 36) tubes.

6. Tubular reactor according to one of the previous claims, wherein each of the first (30, 34) and second (32, 36) tubes has a substantially circular section.

7. Tubular reactor according to one of the previous claims, wherein at least one of the first (30, 34) and second (32, 36) tubes comprises a plurality of gas-permeable

openings (48), substantially aligned parallel to the first (40, 44) or to the second (42, 46) secondary axis.

5 **8.** Tubular reactor according to claim 7, wherein the support (15) comprises a device (75) for the angular positioning of the at least one of the first (30, 34) and second (32, 36) tubes, so that the plurality of gas-permeable openings (48) is placed substantially opposite the main axis (20) relative to the first (40, 44) or to the second (42, 46) secondary axis.

10 **9.** Tubular reactor according to one of the previous claims, comprising a plurality of first tubes (30, 34) and a plurality of second tubes (32, 36), the reactor also comprising: a first end compartment (17), opening on a first end (50) of the first tubes; and a second end compartment (18), opening on a second end (54) of the second tubes.

15 **10.** Method for manufacturing a tubular reactor (10) according to one of the previous claims, comprising the following steps:

- making the first (30, 34) and second (32, 36) tubes; and making the support (15); then
- fixing the support to the first (30, 34) and to the second (32, 36) tubes; then
- 20 - introducing the support and the first and second tubes in the casing (12), so as to form the intermediate space (28).