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(54) Title: REACTOR MULTI-PASS GRIDS FOR IMPROVED CATALYST HYDRODYNAMICS

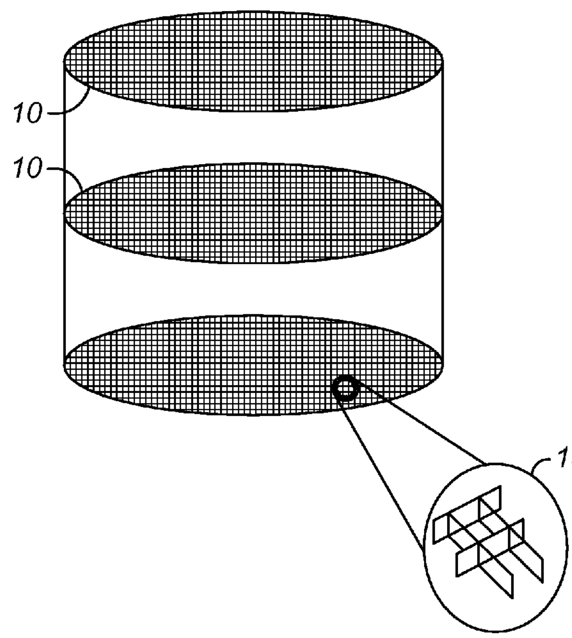

FIG. 1

(57) Abstract: A process and device for the flow of catalyst in a reactor is presented. The device includes a series of grids within a reactor vessel, where each grid includes small openings for the passage of gas and some catalyst particles, and larger openings for the more continuous passage of catalyst. The grids span horizontally across the vessel, and are spaced vertically apart to provide for the flow of catalyst down through the reactor.

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REACTOR MULTI-PASS GRIDS FOR IMPROVED CATALYST HYDRODYNAMICS

STATEMENT OF PRIORITY

[0001] This application claims the benefit of U.S. Provisional Application Nos. 61/806,486 and 61/806,493 which were both filed on March 29, 2013; and U.S. Application Nos. 14/225,464 and 14/225,465 which were both filed on March 26, 2014.

FIELD OF THE INVENTION

[0002] The present invention relates to processes and apparatuses utilizing reactor internals for the distribution of catalysts in a reactor. Specifically, this invention relates to designs for the internals of an MTO reactor to provide for a better distribution of catalyst and contacting of the catalyst with the reactants.

BACKGROUND OF THE INVENTION

[0003] Ethylene and propylene, or light olefins, are important for the production of commercially important plastics, namely polyethylene and polypropylene. Other important polymer precursors include vinyl chloride, ethylbenzene, ethylene oxide and other compounds, which are derived from the light olefins. The production of light olefins is primarily produced through the cracking of heavier hydrocarbons from hydrocarbon feedstocks derived from petroleum.

[0004] A light olefin plant is a combination of reactors and gas recovery systems. The reactors include cracking units for generating a stream having light olefins and fractionation units for separating the light olefins from the other hydrocarbon components in the product streams from the reactors.

[0005] The increasing demand for light olefins has led to the search for other sources as the cost of petroleum has increased. Among the new sources include oxygenates that can be derived from biomass, and other sources. Common oxygenates include alcohols and in particular methanol. In particular, natural gas comprising primarily methane can be converted to methanol, and the methanol can be converted to light olefins. The oxygenates are converted through a reaction process to generate a product stream comprising light olefins.

[0006] One conversion process is generally referred to as methanol to olefins (MTO) process, and the process involves a catalytic reaction and is carried out in a catalytic reactor to generate a product stream of light olefins. The catalyst for the conversion of oxygenates to olefins include solid catalyst such as zeolites. Zeolites used in the MTO process are described in numbers patents. A process for preparing zeolites is described in US 3,957,689. A process for making an improved attrition resistant catalyst is described in US 4,987,110. A process for producing hardened microspheres is described in US 5,352,645. Numerous other patents describe the making of better catalyst for improved reactions, and for improved hardness of the catalyst particles.

[0007] Catalysts having improved attrition resistance is important because the reactor environment is a severe physical environment. The MTO reactor is generally a fluidized bed and the catalyst particles are subject to constant contact and rubbing against other catalyst particles and with physical equipment where the catalyst particles are transferred through, or stirred within.

[0008] Improving the system for the production of light olefins can increase the catalyst life and improve the process to make the production more economical.

SUMMARY OF THE INVENTION

[0009] The present invention is a process and device for improving the contact and yields of light olefins generated in an oxygenate conversion process. The apparatus comprises a plurality of grids disposed within the reactor, where the grids are comprised of small openings and at least one large opening. The large openings facilitate the flow of catalyst while minimizing the catalyst holdup, and direct the catalyst to flow at least partially across the grids as the catalyst flows down the reactor.

[0010] The process comprises flowing a oxygenate rich stream over the catalyst in a generally counter-current flow, with the catalyst flowing down the reactor vessel and the gas flowing up the vessel. The process contacts the oxygenate rich stream with the catalyst at reaction conditions, while flowing the catalyst in a generally serpentine path down the reactor vessel. The movement of the catalyst minimizes the formation of dense catalyst regions, and minimizes catalyst segregation in the process.

[0011] Other objects, advantages and applications of the present invention will become apparent to those skilled in the art from the following detailed description and drawings.

BRIEF DESCRIPTION OF THE DRAWING

[0012] Figure 1 shows a grid structure for the full coverage of the cross-section of an MTO reactor; and

[0013] Figure 2 shows one grid structure for allowing the catalyst to flow more smoothly down the reactor.

DETAILED DESCRIPTION OF THE INVENTION

[0014] There are many reactor processes that utilize fluidized catalyst beds. The catalyst beds are fluidized for providing good contact between the catalyst and reactants. A methanol to olefins (MTO) reactor utilizes a deep catalyst bed. Along with improving the catalyst, improving the conditions within the reactor are also important. The catalyst bed in the MTO is a deep fluidized catalyst bed and flows downward through the reactor. Deep catalyst bed can develop regions where the catalyst does not flow well, and where gas can be maldistributed within the reactor. To improve the movement of catalyst within the reactor and the flow and contact with the gas reactants, vertical plates, or grids, were placed within the reactors. The grids contributed to improving the uniformity of catalyst within the reactor bed. This leads to improve product yields. The grids extend horizontally across the reactor bed and are positioned at multiple elevations within the catalyst bed.

[0015] The grids are designed to achieve a sufficient open area, or cross-sectional area, so as to not affect the process, while still maintaining adequate strength to support the grids. If the cross sectional area of the grids is too high, the flow of catalyst can be restricted and lead to poorer reactor performance through localized catalyst segregation. A grid structure, as shown in Figure 1, shows the internals for an MTO reactor. Figure 1 shows a stack of three grids 10 that are placed within a reactor vessel. The catalyst enters the top of the reactor and flows down through the reactor and through each of the grids 10. The grids 10 are made of welded strips of metal to form a lattice structure having openings sufficient for the catalyst to flow downward and the gas to flow upward in the reactor. The metal strips are typically 2 to 5 mm thick with a width between 10 and 20 mm, but can have a greater thickness or width, depending on the size of the reactor and the strength needed for the grid within the reactor. The lattice structure formed will have substantially rectangular, or square, openings having a side measurement from 10 to 50 mm. The grids are designed to have a large open area, and preferably the open area is greater than 65% of the cross sectional area, and more preferably greater than 75%.

[0016] A problem with a uniform grid arises from the counter-current flow patterns of catalyst and gas. The grids facilitate the flow of catalyst in a uniform direction by limiting the upward and downward motion of the catalyst. However, the flow of gas and the spectrum of particle sizes of the catalyst creates some segregation of the catalyst and creates regions of increased catalyst densities and regions of lower catalyst densities. This is due to smaller particles of catalyst being held up and having greater difficulty flowing across the grids.

[0017] The present invention is directed to improving the flow of catalyst through the direction of large scale flow of catalyst through the reactor and to limit or prevent the creation of localized high velocity areas and localized non-uniform catalyst density regions. The process for this invention concerns contacting an oxygenate feedstream with the catalyst, while flowing the catalyst down through the reactor and flowing the feedstream up through the reactor.

[0018] Figure 1 shows the layout for three grids used in a normal reactor, wherein the grids 10 span the entire cross-section of a reactor. Figure 1, also shows an inset 15, showing an enlargement of a section of a grid. The grid is open and allows for the flow of catalyst through the grid, while also allowing for the flow of fluid in an opposing direction, or upward, through the grid.

[0019] The present invention includes a reactor for contacting a solid catalyst with fluid reactants. The reactor comprises a vessel, where the vessel has an inlet for the catalyst, an outlet for the catalyst, an inlet for the fluid, and an outlet for the fluid. In one embodiment, the fluid is a gas, where the solid flows downward, and the gas flows upward. The interior of a reactor is shown in Figure 2, where there are a plurality of grids 20 disposed within the reactor vessel. The grids 20 extend horizontally across the vessel, and there is a vertical spacing between each pair of grids 20. The grids 20 include a plurality of small openings 25 of sufficient size to allow gas through the openings 25, and of sufficient size to allow the catalyst particles to flow through the openings 25. The grids 20 also include at least one large opening 27 in the grid. The large openings 27 are sufficiently large to allow for the catalyst particles to flow freely.

[0020] The large openings 27 in each grid comprise an open space of between 15% and 35% of the total cross-sectional area. Preferably, the large openings comprise an open space between between 15% and 25% of the total cross-sectional area.

[0021] The grids 20 are disposed within the reactor in a vertical stacking, with vertical spacing between each pair of grids 20. With respect to neighboring grids, each grid has a horizontal orientation, and the large openings are offset in the horizontal direction relative to the large openings of neighboring grids 20. The large openings 27 are substantially rectangular, having a width and a length, with the length greater than the width. The large openings 27 have a width between 5 and 50 mm. In a preferred embodiment, the large openings 27 are substantially rectangular or trapezoidal in shape, and the length of the large openings 27 span the grid from one edge to an opposing edge.

[0022] In one embodiment, the reactor grids 20 comprise a plate with small openings distributed over the plate. Each grid 20 spans the horizontal cross-section of the reactor vessel, and has at least on end that is spaced at least 10 mm from one side of the vessel. This spacing between the grid and the vessel wall provides a large opening, as defined in the present invention. In an alternate embodiment, the reactor can have grids having spacing between the wall and the grid, wherein neighboring grids have the spacing between the wall and the grid on opposite sides of the vessel. The openings in each grid 20 provide a total open area to allow catalyst and fluid to flow, between 50% and 90% of the total cross-sectional area of a grid. In a preferred embodiment, the total open space, or sum of the spaces of the openings, provides a total open area that is between 70% and 85% of the total cross-sectional area.

[0023] Preferably, the reactor includes at least three grids 20 stacked within the vessel in a vertical arrangement. Each grid has at least two large openings that are substantially rectangular, or trapezoidal, in shape, and where each large opening in the grid spans the width of the grid. The large openings of neighboring grids are also displaced, in a horizontal direction relative to the large openings of a neighboring grid.

[0024] In one embodiment, the reactor grids comprise a structure for controlling the flow of catalyst particles through a reactor vessel, wherein the grid has a cross-sectional area and is disposed in a substantially perpendicular orientation relative to the movement of catalyst. The grid 20 comprises a plurality of small openings wherein each small opening 25 has a small dimension between 5 mm and 25 mm. The grids further include at least one large opening, wherein each large opening has a small dimension of at least 75 mm. The large openings in each grid comprises between 15% and 35% of the total cross-sectional area, and preferably between 20% and 30% of the total cross-sectional area.

[0025] In one embodiment, a grid comprises two large openings, and wherein each of the two large openings comprises between 5% and 20% of the total cross-sectional area, with the sum of the two openings comprising at least 15% of the total cross-sectional area. In a preferred embodiment each large opening comprises between 5% and 15% of the total cross-sectional area.

[0026] In another embodiment, the large opening is disposed on one side of the grid between the edge of the grid and the vessel wall, and comprises between 15% and 25% of the total cross-sectional area.

[0027] In one embodiment, the grid comprises a series of intersecting metal strips oriented perpendicular to the plane of the grid. The intersecting metal strips form a lattice structure comprising small openings and at least one large opening.

[0028] The addition of multi-pass grids will prevent the formation of increased catalyst density areas from forming, and improve the overall flow of catalyst through the reactor vessel. This provides for improved contact between the catalyst and fluid, and improves reactor yields. The grids prevent localized high velocity areas with respect to the vertical movement of the catalyst. The catalyst is not allowed to freely flow down from the top of the reactor to the catalyst outlet. The catalyst flows downward, but also is directed to flow across, or partially across, the reactor. This provides for catalyst mixing, as well as breaking up of void spaces and prevents the formation of high density catalyst volumes. The improved flow patterns due to the grid design reduces catalyst segregation.

[0029] The smaller openings provide for fluid, or gas, flow upward, but allows for some catalyst flow through the small openings. With just an array of small openings, the catalyst can segregate and gas flow will preferentially find a path of least resistance, thereby creating segregated catalyst regions. The large openings direct the catalyst and facilitate the flow of catalyst through the reactor and minimize the segregation of catalyst.

[0030] Another aspect of the invention is a process for the production of olefins from oxygenates. The process includes passing a catalyst to a reactor, as described above. The catalyst flows down through the reactor, and a feedstream comprising oxygenates is passed to the reactor through a reactor inlet disposed near the bottom of the reactor vessel. The feedstream flows upward and over the catalyst, reacting and generating an outlet process stream comprising olefins. The grids provide for the flow of catalyst across at least part of the reactor vessel as the catalyst flows downward through the reactor.

[0031] The feedstream comprises a fluid having oxygenates. The oxygenates can include alcohols, ethers, aldehydes, ketones, carboxylic acids, and mixtures thereof. In a preferred embodiment of the process, the oxygenates include alcohols and ethers. It is more preferred that the feed comprises methanol, or dimethyl ether, or a combination of both.

[0032] The present invention uses any appropriate catalyst for the conversion of oxygenates to olefins. A preferred catalyst is a zeolite or a non-zeolitic molecular sieve. A preferred catalyst comprises a silicoaluminophosphate (SAPO).

[0033] The process is operated at reaction conditions to convert the oxygenates to olefins over the catalyst. The reaction conditions include a temperature in the range from 200°C and 700°C, with a preferred range from 300°C to 600°C. The pressures in the reactor for the conversion are between 100 kPa to 10 MPa, with a preferred range from 170 kPa to 2 MPa.

[0034] While the invention has been described with what are presently considered the preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but it is intended to cover various modifications and equivalent arrangements included within the scope of the appended claims.

SPECIFIC EMBODIMENTS

[0035] While the following is described in conjunction with specific embodiments, it will be understood that this description is intended to illustrate and not limit the scope of the preceding description and the appended claims.

[0036] A first embodiment of the invention is a reactor for contacting a solid catalyst with fluid reactants comprising a vessel having a catalyst inlet, a catalyst outlet, a gas inlet and a gas outlet; a plurality of grids disposed within the vessel and extend horizontally across the vessel, and with a vertical spacing between pairs of grids, wherein each grid comprises a plurality of small openings of sufficient size to allow gas through and the catalyst particles through; and at least one large opening for allowing catalyst particles to flow freely through the grid. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein each grid has a cross-sectional area, and the at least one large opening comprises between 15% and 35% of the cross-sectional area. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein each grid has a cross-sectional area, and the at least one large opening comprises between 15% and 25% of the cross-sectional area. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein the girds have a horizontal orientation within the vessel and are spaced vertically. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein the grids have a horizontal orientation and where neighboring grids have large openings offset in the horizontal direction relative to the large openings of neighboring grids. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein the large openings are substantially rectangular, and span across the grid, and have an opening width between 5 and 50 mm. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein each grid comprises a plate with small openings distributed over the plate, and each grid spans the horizontal cross-section of the vessel and has an end that is spaced at least 10 mm from one side of the vessel, wherein the space between the vessel wall and the grid defines the large opening. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein alternating grids have the space between the grid and vessel wall on opposite sides of the vessel. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein the reactor comprises at least three grids stacked within a vessel in a vertical arrangement, and where each grid has at least two large opening that are substantially rectangular, and where the openings span the width of the grid, and wherein the large openings are displaced in a horizontal direction relative to the large openings of a neighboring grid. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein the grids have a total open area for the flow of catalyst and fluid between 50% and 90% of the total cross sectional area.

[0037] A second embodiment of the invention is a reactor grid comprising a structure for controlling the flow of catalyst particles through a reactor vessel wherein the structure has a cross-sectional area, and is disposed in a substantially perpendicular orientation relative to the movement of catalyst, comprising a plurality of small openings wherein each small opening has a small dimension between 5 and 25 mm; and at least one large opening wherein the large opening has a minimum small dimension of at least 75 mm; wherein the large opening comprises between 15% and 35% of the cross-sectional area of the structure. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein the large opening comprises between 20% and 30% of the cross-sectional area. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein the at least one large opening comprises two openings, and wherein each of the two large openings comprise between 5% and 20% of the cross-sectional area of the structure. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein the grid comprises one large opening on one side of the grid and comprising between 15% and 25% of the cross sectional area of the grid, and where the remainder of the grid is comprised of small openings. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein the grid comprises at least two large openings, wherein each opening is a substantially rectangular opening that spans across the grid, and wherein each large opening comprises between 5% and 15% of the cross sectional area of the grid, and where the remainder of the grid is comprised of small openings. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein the grid is comprised of a series of intersecting metal strips oriented perpendicular to the plane of the grid, and wherein the intersecting metal strips form a lattice structure comprising small openings and at least one large opening. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein the grid is comprised of a metal plate having holes distributed throughout the plate, and wherein the plate includes at least one large opening comprising between 15% and 25% of the total cross sectional area of the grid. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein the total open area for the flow of catalyst and fluid is between 50% and 90% of the total cross sectional area An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein the total open area for the flow of catalyst and fluid is between 70% and 85% of the total cross sectional area.

[0038] A third embodiment of the invention is a process for the production of olefins from oxygenates comprising passing a catalyst to a reactor for contacting a solid catalyst with fluid reactants comprising a vessel having a catalyst inlet, a catalyst outlet, a gas inlet and a gas outlet; a plurality of grids disposed within the vessel and extend horizontally across the vessel, and with a vertical spacing between pairs of grids, wherein each grid comprises a plurality of small openings of sufficient size to allow gas through and the catalyst particles through; and at least one large opening for allowing catalyst particles to flow freely through the grid; and passing a fluid stream comprising oxygenates over the catalyst. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the third embodiment in this paragraph wherein each grid in the reactor has a cross-sectional area, and the at least one large opening comprises between 15% and 35% of the cross-sectional area. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the third embodiment in this paragraph wherein each grid in the reactor has a cross-sectional area, and the at least one large opening comprises between 15% and 25% of the cross-sectional area. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the third embodiment in this paragraph wherein the girds within the reactor have a horizontal orientation within the vessel and are spaced vertically. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the third embodiment in this paragraph wherein the fluid stream comprising oxygenates includes oxygenates selected from the group consisting of alcohols, ethers, aldehydes, ketones, carboxylic acids, and mixtures thereof. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the third embodiment in this paragraph wherein the large openings in the grids are substantially rectangular, and span across the grid, and have an opening width between 5 and 50 mm. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the third embodiment in this paragraph wherein each grid in the reactor comprises a plate with small openings distributed over the plate, and each grid spans the horizontal cross-section of the vessel and has an end that is spaced at least 10 mm from one side of the vessel, wherein the space between the vessel wall and the grid defines the large opening. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the third embodiment in this paragraph wherein the catalyst comprises a molecular sieve comprising silicoaluminophosphates. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the third embodiment in this paragraph wherein the reactor comprises at least three grids stacked within a vessel in a vertical arrangement, and where each grid has at least two large opening that are substantially rectangular, and where the openings span the width of the grid, and wherein the large openings are displaced in a horizontal direction relative to the large openings of a neighboring grid. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the third embodiment in this paragraph wherein the grids in the reactor have a total open area for the flow of catalyst and fluid between 50% and 90% of the total cross sectional area.

[0039] A fourth embodiment of the invention is a process for converting oxygenates to olefins, comprising passing a catalyst through a reactor, wherein the reactor includes a plurality of reactor grids, with each reactor grid comprising a structure for controlling the flow of catalyst particles through a reactor vessel wherein the structure has a cross-sectional area, and is disposed in a substantially perpendicular orientation relative to the movement of catalyst, comprising a plurality of small openings wherein each small opening has a small dimension between 5 and 25 mm; and at least one large opening wherein the large opening has a minimum small dimension of at least 75 mm; wherein the large opening comprises between 15% and 35% of the cross-sectional area of the structure; and passing a fluid stream comprising oxygenates over the catalyst at reaction conditions in the reactor to generate a process stream comprising olefins. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the fourth embodiment in this paragraph wherein in each reactor grid the large opening comprises between 20% and 30% of the cross-sectional area. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the fourth embodiment in this paragraph wherein in each reactor grid the at least one large opening comprises two openings, and wherein each of the two large openings comprise between 5% and 20% of the cross-sectional area of the structure. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the fourth embodiment in this paragraph wherein the grid comprises one large opening on one side of the grid and comprising between 15% and 25% of the cross sectional area of the grid, and where the remainder of the grid is comprised of small openings. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the fourth embodiment in this paragraph wherein the catalyst comprises a zeolite or non-zeolitic molecular sieve. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the fourth embodiment in this paragraph wherein the catalyst comprises a silicoaluminophosphate (SAPO). An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the fourth embodiment in this paragraph wherein the reaction conditions include a temperature between 200°C and 700°C. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the fourth embodiment in this paragraph wherein the fluid stream comprising oxygenates are selected from the group consisting of alcohols, ethers and mixtures thereof. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the fourth embodiment in this paragraph wherein the reaction conditions include a pressure between 100 kPa and 2000 kPa.

[0040] Without further elaboration, it is believed that using the preceding description that one skilled in the art can utilize the present invention to its fullest extent and easily ascertain the essential characteristics of this invention, without departing from the spirit and scope thereof, to make various changes and modifications of the invention and to adapt it to various usages and conditions. The preceding preferred specific embodiments are, therefore, to be construed as merely illustrative, and not limiting the remainder of the disclosure in any way whatsoever, and that it is intended to cover various modifications and equivalent arrangements included within the scope of the appended claims.

[0041] In the foregoing, all temperatures are set forth in degrees Celsius and, all parts and percentages are by weight, unless otherwise indicated.

CLAIMS:

1. A process for the production of olefins from oxygenates comprising:

passing a catalyst to a reactor for contacting a solid catalyst with fluid reactants comprising:

a vessel having a catalyst inlet, a catalyst outlet, a gas inlet and a gas outlet;

a plurality of grids disposed within the vessel and extend horizontally across the vessel, and with a vertical spacing between pairs of grids, wherein each grid comprises:

a plurality of small openings of sufficient size to allow gas through and the catalyst particles through;

and at least one large opening for allowing catalyst particles to flow freely through the grid; and

passing a fluid stream comprising oxygenates over the catalyst. wherein the reactor comprises at least three grids stacked within a vessel in a vertical arrangement, and where each grid has at least two large opening that are substantially rectangular, and where the openings span the width of the grid, and wherein the large openings are displaced in a horizontal direction relative to the large openings of a neighboring grid, and wherein the grids in the reactor have a total open area for the flow of catalyst and fluid between 50% and 90% of the total cross sectional area.

2. The process of claim 1 wherein each grid in the reactor has a cross-sectional area, and the at least one large opening comprises between 15% and 35% of the cross-sectional area.

3. The process of claim 1 wherein the girds within the reactor have a horizontal orientation within the vessel and are spaced vertically.

4. The process of claim 1 wherein the fluid stream comprising oxygenates includes oxygenates selected from the group consisting of alcohols, ethers, aldehydes, ketones, carboxylic acids, and mixtures thereof.

5. The process of claim 1 wherein the large openings in the grids are substantially rectangular, and span across the grid, and have an opening width between 5 and 50 mm.

6. The process of claim 1 wherein each grid in the reactor comprises a plate with small openings distributed over the plate, and each grid spans the horizontal cross-section of the vessel and has an end that is spaced at least 10 mm from one side of the vessel, wherein the space between the vessel wall and the grid defines the large opening.

7. The process of claim 1 wherein the catalyst comprises a molecular sieve comprising silicoaluminophosphates.

8. A reactor for contacting a solid catalyst with fluid reactants comprising:

a vessel having a catalyst inlet, a catalyst outlet, a gas inlet and a gas outlet;

a plurality of grids disposed within the vessel and extend horizontally across the vessel, and with a vertical spacing between pairs of grids, wherein each grid has a horizontal orientation within the vessel, and are spaced vertically comprises:

a plurality of small openings of sufficient size to allow gas through and the catalyst particles through;

and at least one large opening for allowing catalyst particles to flow freely through the grid, and wherein the grids have a total open area for the flow of catalyst and fluid between 50% and 90% of the total cross sectional area, and wherein the grids have a horizontal orientation and where neighboring grids have large openings offset in the horizontal direction relative to the large openings of neighboring grids.

9. The reactor of claim 1 wherein each grid has a cross-sectional area, and the at least one large opening comprises between 15% and 35% of the cross-sectional area.

10. The reactor of claim 1 wherein the large openings are substantially rectangular, and span across the grid, and have an opening width between 5 and 50 mm.

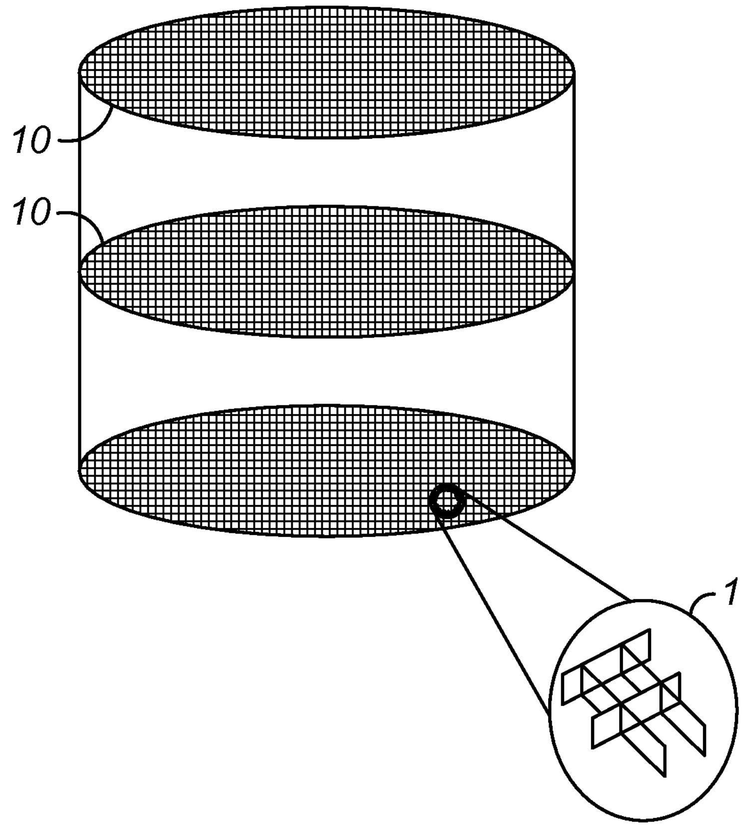

FIG. 1

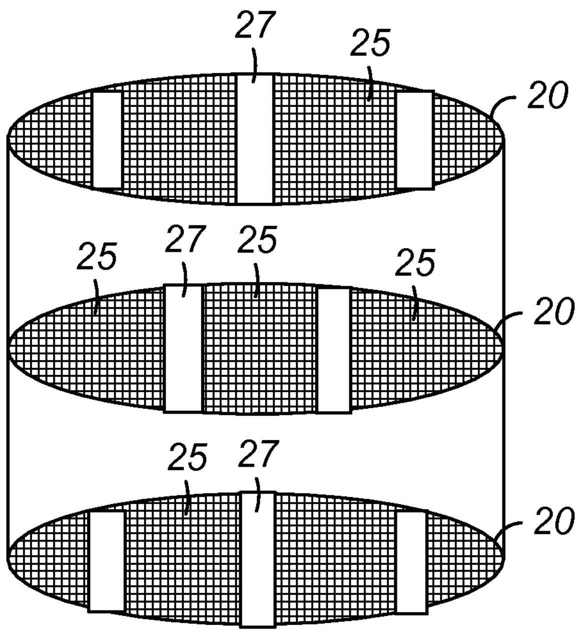

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/031968

A. CLASSIFICATION OF SUBJECT MATTER

C07C 7/20(2006.01)i, C07C 63/04(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C07C 7/20; B01J 8/28; B01J 8/18; C07C 1/20; C08F 210/00; F16L 51/02; B01J 8/24; C07C 63/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: olefins, oxygenates, catalyst, a plurality of grids, reactor vessel

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6235246 B1 (KAO, THOMAS Y.) 22 May 2001 See abstract; Fig. 1; and example.	1-10
A	US 06113862 A (JORGENSEN, ROBERT JAMES et al.) 05 September 2000 See abstract; Fig. 1, Fig. 2; and column 7, line 58-column 8, line 8.	1-10
A	US 7232936 B1 (YURCHAK, SERGEI) 19 June 2007 See abstract; Figure; and claims 1, 11.	1-10
A	US 2010-0267915 A1 (BERGSTRA, MICHIEL et al.) 21 October 2010 See abstract.	1-10

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 August 2014 (27.08.2014)	**27 August 2014 (27.08.2014)**

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