BED SUPPORT MEDIA

BACKGROUND

FIELD OF THE INVENTION

[0001] The present exemplary embodiment relates to bed support media. It finds particular application in conjunction with support media for a catalyst bed, and will be described with particular reference thereto. However, it is to be appreciated that the present exemplary embodiment is also amenable to other like applications.

DISCUSSION OF THE ART

[0002] In some catalytic reactors, a catalyst bed is formed of a carrier material, typically comprising particulate elements, which supports a catalytic material, such as a metal or metal oxide. Carriers, or catalyst supports, as they are often known, are commonly inorganic materials such as refractory inorganic materials, for example alumina-, silica-, or titania-based compounds, or combinations of these, such as alumina-silica carriers. Carriers may also be formed from carbon-based materials such as, for example, charcoal, activated carbon, or fullerenes. The carrier may have a porous or open structure, such as a ring, honeycomb, or wagon wheel, which provides a large geometric surface area on which the catalyst is supported.

[0003] Where the catalyst bed is relatively shallow, the bed may be supported on a foraminous plate, crossed beams, or a similar structure. For beds of greater depth, and consequently greater weight, the catalyst bed is supported in a tower, on a second bed, or support bed, which is typically formed of individual ceramic spheres. Spheres are used to have sufficient strength to support the weight of the catalyst bed and, in the case of the lowermost spheres, the entire weight of the support bed. The spheres are generally of larger diameter than the elements of the catalyst bed that they support. The spherical elements in a support bed have a void fraction, measured as a percentage, of up to about 36%, due to the spaces between the elements. These spaces or voids allow the reactant material to pass through the support bed either before or after coming into contact with the catalyst bed above, depending on the direction of flow. Pellets have also been used as support elements, which, due to their shape, may have slightly higher void fraction than spheres.

SUMMARY

[0004] In accordance with one aspect of the present exemplary embodiment, a system for treatment of one or more flowing materials is provided. The system includes a shell and a support bed in the shell comprising a plurality of support elements. The support bed has a void fraction of at least 50%. An active bed in the shell is supported by the support bed. The support bed has an activity towards the one or more flowing materials which is less than 20% of that of the active bed on a basis of weight.

[0005] In accordance with another aspect of the present exemplary embodiment, a system for treatment of one or more flowing materials is provided. The system includes a support bed comprising a plurality of non-spherical support elements. The support elements each define at least one through passage. A bed comprising a plurality of active elements is supported by the support bed. The support elements have an activity per unit weight towards the flowing materials which is no greater than 20% of the activity per unit weight of a majority of the active elements in the bed of active elements.

[0006] In accordance with another aspect of the present exemplary embodiment, a system for treatment of a fluid material is provided. The system includes a shell having a base at a lower end thereof and an inlet and an outlet for the fluid material. A column of elements is within the shell through which the fluid material passes. The column includes a support bed of elements. The support bed includes the elements of the column that are closest to the base. The support bed has a void fraction of at least 50%. An active bed of elements is supported by the support bed for treatment of the fluid material.

[0007] In accordance with another aspect of the present exemplary embodiment, a system for treatment of a fluid material is provided. The system includes a shell having a base at a lower end thereof and an inlet and outlet. One of the inlet and the outlet is closer to the base than the other of the inlet and outlet. A column of elements is within the shell through which the fluid material passes between the inlet and the outlet. The column includes an active bed of active elements for treatment of the fluid material and a support bed which supports the active bed thereon. The support bed includes a plurality of elements each having at least one through passage. The support bed includes those elements of the column that are closest to the one of the inlet and outlet that is closer to the base. The support bed has a void fraction of at least 45%.

[0008] In accordance with another aspect of the present exemplary embodiment, a method of forming a system for treatment of a flowing material is provided. The method includes placing a plurality of support elements in a column to form a support bed. The support bed has a void fraction of at least 50%. A layer of the support bed is formed which defines a lowermost layer of elements in the column. A bed of active elements is supported on the support bed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIGURE 1 is a side sectional view of a treatment system according to the present invention;

[0010] FIGURE 2 is a top plan view of a support element according to a first embodiment of the present invention;

[0011] FIGURE 3 is a side elevational view of the support element of FIGURE 2;

[0012] FIGURE 4 is a perspective view of randomly dumped support elements;

[0013] FIGURE 5 is a top plan view of a support element according to a second embodiment of the present invention;

[0014] FIGURE 6 is a top plan view of a support element according to a third embodiment of the present invention;

[0015] FIGURE 7 is a top plan view of a support element according to a fourth embodiment of the present invention;

[0016] FIGURE 8 is a top plan view of a support element according to a fifth embodiment of the present invention;

[0017] FIGURE 9 is a top plan view of a support element according to a sixth embodiment of the present invention;

[0018] FIGURE 10 is a theoretical plot of pressure drop, in centimeters water/ meter of bed vs. gas mass velocity in kg/hr.m^2 for a bed of the support elements of FIGURE 2 and a bed of spherical support elements of an equivalent diameter; and

[0019] FIGURE 11 is a plot of actual pressure drop, in cm water/m of bed vs. gas velocity in kg/hr.m^2 for a bed of the support elements of FIGURE 2 and a bed of spherical support elements of an equivalent diameter.

DETAILED DESCRIPTION

[0020] An important factor in maximizing efficiency of the catalyst bed is the maintenance of an adequate flow rate of the reactant materials through the bed. While shallow catalyst beds may experience a high flow rate with an acceptable pressure drop across the bed, maintaining this flow rate as the depths of the catalyst bed and of the support bed increase results in increasing pressure drop across the bed. It is desirable to achieve as low a pressure difference between the top and bottom of the bed as possible. In the past, this has been achieved by designing the carrier elements in the catalyst bed such that they present reduced resistance to flow. However, there are limits to the pressure drop reductions that may be obtained in this way while maintaining a desired catalytic activity.

[0021] With reference to FIGURE 1, a system for treatment of one or more flowing materials is shown. The system may be any type of treatment system, such as a sequestering system or a catalytic treatment system. The system is generally illustrated herein as a catalytic treatment system by way of example. In a catalytic treatment system, the flowing materials may include reactant materials.

[0022] The system may include a shell or tower **10** that defines an interior chamber **12** and an inlet **14** and an outlet **16**, through which one or more fluid reactant materials, such as a gases and/or liquids, enter and leave the chamber. The outlet **16** may be formed in a side wall **18** adjacent to a base **20** of the tower or formed within the base itself and the inlet is formed in or adjacent an upper wall **22** of the tower. In the illustrated embodiment, the reactant material flows downward through the tower. It will be appreciated, however, that the locations of the inlet **14** and outlet **16** may be reversed and the reactants may flow upward through the tower.

[0023] A column of discrete elements **30** within the chamber includes a support bed **32**, which is disposed adjacent the base **20** of the chamber **12**. The support bed includes a plurality of discrete support elements **34** that are located within the shell. The support bed provides support for an active bed **36**, such as a catalyst bed or sequestering bed, the weight of which is carried thereon. The support elements may be placed in the shell by dumping them into in the shell to provide a substantially random arrangement of surfaces. Catalyst bed **36** is supported on the support bed **32** and comprises a plurality of discrete catalytic elements **38** that are located within the shell. The catalytic elements may also be placed by dumping to provide a

random arrangement of surfaces that provide tortuous paths for the flow of the reactant material, or arranged in a more ordered fashion. The catalytic elements **38** may comprise a carrier that supports a catalytic material, such as a metal or metal oxide, capable of catalyzing a reaction of one or more components of the reactant materials, or be otherwise formed to have catalytic activity.

[0024] In one embodiment, the support elements **34** are arranged in a plurality of layers **40, 42.** The support bed typically includes the lowermost layer of elements of the column **30**. In the illustrated embodiment, this is layer **42**, which is supported only by the gravitational base **20** of the reactor and not by any other discrete elements. Two layers **40, 42** are illustrated in FIGURE 1, by way of example, although fewer or more layers may be used, such as one, three, or four layers. In one embodiment, only two layers **40, 42** are used. The average size of the elements in one layer (for example, expressed in terms of the mean diameter, where the diameter of an element is determined, for example, as the average width of the element or the maximum width) differs from that of the adjacent layer. In one embodiment, the average size of the support elements **34** in uppermost layer **40**, closest to the catalyst bed **36,** is less than that of the next layer **42**, which, in turn, is less than that of any subsequent layer, and so on to the lowest layer (layer **42** in the illustrated embodiment). The sizes may be chosen so as to hold the catalyst in place without appreciable percolation of the catalytic elements through the support bed. For example, the lowermost layer **42** may comprise elements having an average size of about 10 mm, and layer **40**, elements of an average size of about 6 mm. It will be appreciated that the actual sizes may depend, to some degree, on the size of the catalyst elements. Typically, the average diameter of the support elements in the uppermost layer is at least about 1-2 mm greater than the average diameter of the adjacent catalyst elements. For example, the catalyst elements may be pellets of about 3 mm in diameter with a ratio of diameter to length of about 1:2 to 1:3 and the support elements in first layer 40 may have a diameter of about 6 mm. Two or more additional layers of elements may be added below the two layers illustrated, for example, layers with average sizes of about 24-50 mm and 19 mm, respectively.

[0025] The support elements **34** may be non-spherical. In some embodiments, the support elements may be formed to permit passage of reactants through the elements, rather than simply around the elements, as in a conventional support bed of pellets or spheres. While a conventional support bed typically has four or more layers of increasing size towards the bottom of a reactor, it has been found that for the non-spherical support elements **34** disclosed herein, fewer layers may be

needed than for spherical or pelletized elements. As a result, the depth of the bed can be less than for a conventional bed. For example, a support bed comprising two layers, or even one layer, can replace a conventional four layer bed of spherical or pelletized elements.

[0026] Having the smallest support elements **34** positioned closest to the catalyst bed provides void spaces **48**, between the support elements **34**, which are generally too narrow for the catalytic elements **38** to pass therethrough to any great degree. In general, this means that the uppermost layer **40** comprises support elements **34** of a larger average size than the catalytic elements **38** of the adjacent catalyst bed **24**. Having increasingly larger support elements **34** towards the lower end of the support bed **32** allows for an increased void fraction and large passages through the bed, which reduces the pressure drop across the bed for a given flow rate while maintaining the strength needed to support the entire catalyst bed and support bed load. The large support elements support the smaller support elements. The larger support elements may be sufficiently large that they do not pass through the inlet or outlet at the bottom end of the reactor and yet small enough to prevent the layer of support elements immediately above them from percolating through. The larger support media may also offer a lower pressure drop for a given flow rate. In the illustrated embodiment, the lower layer **42** is in contact with the base **20** of the reactor.

[0027] As shown in FIGURE 1, each layer of the column typically lies directly on the underlying layer, without any spacers or the like between the layers. However, it is also contemplated that spacers may be interposed between the layers and/or at the top and bottom of the column.

[0028] Optionally a bed limiter **50** is positioned on top of the catalyst bed. The bed limiter helps to reduce the loss of catalyst elements in the upward flow of the reactant in an upward flow reactor and reduces catalyst movement in downflow reactors. A pressure drop across the height of the column **30** includes contributions from the support bed **32**, catalyst bed **36**, bed limiter **50**, where present, and any other layers which may be used. Generally, the catalyst bed accounts for the largest portion of the pressure drop. In one embodiment, the catalyst bed pressure drop is at least four times that of the support bed pressure drop at a typical operating flow rate. By changing from spherical elements to non-spherical elements **34** the pressure drop across the support bed for a particular flow rate can be reduced by about 10% or more in one embodiment, 20% or more in another embodiment, and

50% or more in yet another embodiment. For example, the pressure drop across the support bed may drop from about 20 cm water/ m of bed to about 4 cm water/ m of bed or less, at a given gas mass velocity, when spherical elements are replaced with non–spherical elements with higher void fraction. This difference can be used to increase the rate of flow through of reactants and/or the depth of the catalyst bed while maintaining a consistent pressure drop. This may result in a higher conversion rate for each pass through the reactor.

[0029] In a typical catalytic process in a downflow reactor, one or more reactant materials (e.g., liquid, gas, or vapor) enter the inlet of the chamber and pass downward through the bed delimiter, where present, then the catalyst bed and support bed. In the case of liquid reactant materials, the movement may be unassisted. In some cases, counter-current liquid/gas flow may occur, although generally to a lesser degree. A pump 52, in fluid communication with the inlet or outlet, is optionally used for gaseous or vapor phase reactant materials, or to increase the flow rate of a liquid material. When the reactants enter the catalyst bed, the catalyst associated with the catalytic elements catalyzes one or more reactions of a component or components of the reactant materials. The reaction products, and any residual reactant materials, pass out of the catalyst bed and through the support bed before exiting the reactor via the outlet. It will be appreciated that in an upflow reactor, the direction of flow is reversed, i.e., the reactants material first pass through the support bed and then the catalyst bed before passing through any bed delimiter.

[0030] In certain treatment systems, such as sequestering systems, the active elements 38 may transfer mass between the flowing materials and elements of the active bed 36. It should be appreciated that as used herein, the term "active elements" refers to an element that actively participates in the treatment system, such as by catalyzing a reaction, reacting, or absorbing, adsorbing or desorbing one or more materials. Examples of catalytic processes include hydrotreating, hydrocracking, reforming, isomerization, and oxidation. Examples of sequestering processes include use of the active elements as absorbers or molecular sieves, for drying, separations, and extractions. While the active elements may also serve to distribute flow and/or improve the interfacial area for gas/liquid interactions, the term active elements does not include traditional mass transfer elements whose sole purpose is to distribute flow and/or improve the interfacial area for gas/liquid interactions.

[0031] The support elements **34** are non-spherical. This allows for a larger void fraction of the support bed than can be achieved with spherical support elements and a reduction in the pressure drop across the support bed at a given flow rate. Void fraction, as used herein, is the percentage of the entire volume of the support bed which is not occupied by the support elements, excluding any closed voids and small pores through which the reactant material does not pass at any appreciable rate (i.e., pores with a diameter of less than about 0.3 mm). For example, a bed of spherical, substantially non-porous elements may have a void fraction of no more than about 36%. It should be appreciated that higher and lower void fractions are theoretically possible if the support elements are carefully arranged, but that the values stated herein represent accepted empirical data and the conditions in actual beds, not theoretical values. Another way in which the void fraction/pressure drop reduction can be increased is to provide the support elements **34** with one or more through passages. Conventional pellets that have been used as support elements lack through passages and have a void fraction of no more than 47%. In one embodiment, the void fraction of the entire support bed **32** is at least 45%, in another embodiment, at least 50%, and in one specific embodiment, about 56%. The void fraction of the bed can be up to about 80%, depending on the weight of the bed that is supported thereon. In one embodiment, the void fraction is up to about 75% and in another it is less than about 65%.

[0032] It will be appreciated that the individual layers **40, 42** of the support bed may have different void fractions from that of the overall bed **32**, the void fractions generally being greater as the mean size of the support elements comprising the layer increases. The void fraction of the entire bed **32** is an overall void fraction that takes into account the void fractions of the various layers.

[0033] Even small increases in void fraction can have a significant effect on the efficiency of the bed **32** and of the entire column **30**. For example, a pressure drop across a support bed formed of spherical support elements may be about 140 g/cm^2 at a given flow rate. The bed **32** of non-spherical elements may have a pressure drop at this flow rate which is less than about 80% of that of a bed of an equivalent height of spherical substantially non-porous elements having the same average element size (112 g/cm^2 in the illustrated embodiment). In one embodiment, the pressure drop of the bed **32** is less than 60% of the equivalent spherical element bed, and in another embodiment, the pressure drop is about 50% or less of that of the equivalent bed. In one specific embodiment, the pressure drop is about 20% that of the equivalent bed. The equivalent spherical diameter is determined by

calculating the radius of a sphere having an equivalent volume. In this determination, the outer dimensions of the non-spherical support element are measured to determine the volume. The measured volume thus includes the void spaces created by the through passages within the element.

[0034] The term "non-spherical", and similar terms are used herein to mean an average ratio of minimum dimension to maximum dimension of about 0.70 or less, in one embodiment about 0.6 or less, and in another embodiment, of about 0.5, or less, or having an average sphericity value of less than about 0.70, or 0.6, or 0.5, compared to a Krumbein and Sloss chart. Conventional balls used for support elements, even if not precisely spherical, have an average sphericity value of close to 1.0.

[0035] FIGURES 2 and 3 illustrate an example embodiment of a support element **34**. FIGURE 4 demonstrates intra-element void spaces **48** between randomly dumped elements **34**. The support element **34** includes a containing structure **56** that is essentially cylindrical in shape and this is understood to include perfect cylinders and shapes in which a round cylindrical shape has been somewhat flattened to create an oval cross-section as well as regular and irregular polygonal shapes with at least four, e.g., five or more sides. The space within the containing structure can have a plurality of cross members **58** which serve as structural members connecting one interior part of the cylindrical containing structure with another. In the illustrated embodiment two intersecting cross members **58** form a cross that provides a rigid support for the element.

[0036] The support elements **34** may each include at least one through passage **60**. In the illustrated embodiment, a plurality of through passages **60** and/or peripheral indents **62** extend along the length of the element which contribute to the void fraction. In the illustrated embodiment, four pie piece-shaped through passages **60** are formed between the intersecting cross members **58** and the containing structure **56**. Eight semicircular indents **62** are arcuately spaced around the periphery of the containing structure and extend along the length of the element. Optionally, protrusions **64** extend inward from the containing structure **56**. The protrusions **64** serve to limit the maximum diameter of a catalyst carrier element **38** or smaller support element which can pass through a passage **60** while maintaining an open structure for passage of reactants. In this way, percolation of catalyst elements down through the bed **32** may be reduced.

[0037] The through passages may have a mean cross sectional width **d** of at least 5% of the maximum cross sectional width **D** of the support element (in the illustrated embodiment, **D** is its maximum diameter), and in one embodiment, at least 10%. For smaller elements (i.e., those less than 1 cm in diameter **D**), it may be desirable to have a width **d** that is greater than 10% of the maximum cross sectional width **D** of the support element, as the passages may otherwise be too small to provide desired flow. For example, for a 6 mm diameter element, the passages may be desired to be at least 1 mm in mean cross sectional width. The maximum size of the passages is dependent, to some degree, on the size of the particles in the layer above. For example, the passages are preferably shaped such that the particles in the adjacent layer above are too large to readily fit through the passage **60**, as illustrated by the particle **38** whose periphery is shown by hatched lines. For example, the diameter of the largest circle **66** which can be enscribed within a passage may be smaller than a maximum diameter of elements in the next layer above. Additionally, the periphery of the element may be shaped such that the particles of the next layer above do not readily pass through the inter-particle voids **48**.

[0038] The example support element **34** has upper and lower faces **70, 72** and defining a cross section having a maximum diameter **D**. The element has a length **L** that is perpendicular to the faces. The faces may be planar, as shown, or convex, concave or irregularly shaped. The cross section of the element is generally uniform along the length **L**, in the case of an element formed by an extrusion process. In one embodiment a ratio of D:L is from about 5:1 to about 1:4, e.g., about 3:1.

[0039] It will be appreciated that alternative inner geometries of the support element may be provided, for example, by forming the element with a larger or smaller number of cross members and/or passages. Additionally, the bed support elements of one layer can be differently configured from elements of another layer. For example, the larger elements in the bed may have relatively wider cross members or a larger number of cross members to provide these elements with greater crush strength to support the weight of the bed. It is also contemplated that elements may be formed without cross members, for example, a simple ring-shaped structure. In yet another embodiment, elements of more than one shape and/or size are mixed in a single layer of the support bed.

[0040] In one embodiment, at least 80% of the void fraction of the support bed **32**, and in one embodiment, at least 90% of the void fraction of the bed **32** is derived

from inter-element void spaces **48** and through passages **60** having a mean width of at least 0.5 mm. In this embodiment, the elements **34** are largely formed of non-porous material such that the majority (e.g., at least 90%, and in one embodiment, at least 98%) of the intra-element void fraction comprises through passages **60**. For example, the elements **34** may have an apparent porosity, as measured by ASTM C-373 of less than 14%. In one embodiment, the apparent porosity is less than 7%, in another embodiment, less than 3%, and in another embodiment, less than 1.5%. The elements can have an apparent porosity of less than 0.7%. The low porosity may contribute to the strength of the element. In measuring apparent porosity, the through passages **60** are not taken into account. In general, any porosity of the elements **34** which does exist is provided by fine pores, for example, at least 90% of the pores in the element have a diameter of less than about 50μm.

[0041] The support elements may have sufficient crush strength to support the weight of a column they are to be used with thereon. In one embodiment, the elements that make up the lowermost layer **46** have a crush strength of at least 200lb/sq. in. (14 Kg/cm^2), and in one embodiment, at least 300 lb/sq. in (21 Kg/cm^2). The crush strength can be up to about 400 lb/sq. in. (28 Kg/cm^2), or higher. In one specific embodiment, the crush strength is about 360 lb/sq. in (255 Kg/cm^2). In one embodiment, the crush strength of the support elements is greater than that of the catalyst elements.

[0042] With reference to FIGURES 5-10, alternative embodiments of a support element are shown. These elements can be similar in dimensions and can be similarly formed to the support element **34**, except as otherwise noted. The ratio of D:L, in each case, can be from about 5:1 to about 1:4, e.g., about 3:1.

[0043] The support element **134** shown in FIGURE 5 includes a containing structure **156** that is essentially cylindrical in shape and having indents **162**. Cross members **158** serve as structural members connecting one interior part of the cylindrical containing structure with another. The support element **134** includes four through passages **160**. The element is symmetrical about X and Y axes.

[0044] The support element **234** shown in FIGURE 6 includes a containing structure **256** that is cylindrical in shape without indents. A single cross member **258** connects one interior part of the cylindrical containing structure with another. The support element **234** includes two through passages **260**, which are arcuate in shape. The element is symmetrical about X and Y axes.

[0045] The support element **334** shown in FIGURE 7 includes a containing structure **356** that is essentially cylindrical in shape with cross members **358** which serve as structural members connecting one interior part of the cylindrical containing structure with another. The support element **334** includes six through passages **360**, a circular central passage **360A** and five arcuately spaced circular passages **360B**. Arcuately spaced concave peripheral indents **362** extend along the length of the element and are joined by convex portions **368** of the periphery located adjacent the peripheral through passages **360B**. The element is radially symmetrical about an angle θ equal to 360/5 (the number of peripheral passages **360B**).

[0046] The support element **434** shown in FIGURE 8 includes a containing structure **456** that is cylindrical in shape without indents. Cross members **458** serve as structural members connecting one interior part of the cylindrical containing structure with another. The support element **434** includes twelve through passages **460**, six arcuately spaced interior diamond shaped passages **460A** and six arcuately spaced generally triangular passages **460B**. The element is symmetrical about X and Y axes.

[0047] The support element **534** shown in FIGURE 9 is shaped like a dog bone with a maximum width D along the X axis and a maximum height H perpendicular to the X axis. The ratio of D:H may be about 1:1 to 2:1, e.g., from about 1.2:1 to 1.8:1. A plurality (eleven in the illustrated embodiment) of circular shaped through passages **560** are spaced about the element. Pairs of opposed concave peripheral indents **562A** and **562B** extend along the length of the element which contribute to the void fraction and are spaced from each other or joined by convex portions **568** of the periphery which define the four corners of the element. The concave indents **562A** at ends of the height dimension H can define arcs of an imaginary circle of diameter greater than **D**. The concave indents **562B** at ends of the width dimension D can define an arc of an imaginary circle that is about 40-150% of that of the maximum width D. The element is symmetrical about X and Y axes.

[0048] The support elements of the invention can be formed from any material that provides sufficient strength for the support element and is compatible with the flowing materials to be used. For example metals, plastics, or ceramic materials such natural or synthetic clays, feldspars, zeolites, cordierites, aluminas, zirconia, silica or mixtures of these may be used. Clays are generically mixed oxides of alumina and silica and include materials such as kaolin, ball clay, fire clay, china clay, and the like. Example clays are high plasticity clays, such as ball clay and fire

clay. The clay may have a methylene blue index, ("MBI"), of about 11 to 13 meq/100 gm. The term "feldspars" is used herein to describe silicates of alumina with soda, potash and lime. Other components such as quartz, zircon sand, feldspathic clay, montmorillonite, nepheline syenite, and the like can also be present in minor amounts of the other ceramic-forming components.

[0049] Components fired together to produce ceramic bed support elements may be supplied in fine powder form and may be made into a shapeable mixture by the addition of water and/or processing aids, such as bonding agents, extrusion aids, lubricants, and the like to assist in the extrusion process. The mixture can be processed using several different techniques, such as extrusion or pressing using dry pressing techniques to achieve the desired shape. For example, an initial extrusion process may be followed by cutting perpendicular to the direction of extrusion into the desired lengths. An initial drying may be used to drive off water. This may avoid disrupting the relatively weak structure of the greenware and may be carried out at below about 120°C and, in one embodiment, below about 70°C and may last for about 5 hours. The bodies may then be processed at high temperatures, for example, a maximum temperature of from 1100°C to 1400°C, in one embodiment, at least 1200°C, and in another embodiment, about 1250°C, to form a dense body that typically has less than 1.5% apparent porosity, and in one embodiment, less than 0.7% apparent porosity. However, the porosity may be up to about 15% for some applications. The firing temperature may depend, to some degree, on the composition of the elements, and in general, may be sufficient for the bulk of the material to achieve a low porosity. This is in contrast to reticulated ceramic bodies that typically have up to 30-80% apparent porosity or intra-material voids, and which thus may be unsuited to supporting the weight generally found in certain active beds.

[0050] For example, the ceramic elements may be fabricated from a mixture of clays and feldspars and other minor ingredients to form a resultant body that is comprised mainly of silicon oxide and aluminum oxide (an aluminosilicate). For example, the mixture used to form the elements may comprise at least about 90% of ceramic forming ingredients and the balance (typically up to about 10%) of processing aids. The ceramic forming ingredients may comprise 20-99% aluminum oxide and 0-80% silicon oxide. The processing aids may be largely volatilized during firing. It will be appreciated, however, that the support elements can be composed of any material that is inert, or in some embodiments, beneficially active, to the component streams in the process environment and provides sufficient crush

strength to adequately support a desired column. The components may be thoroughly mixed before water is added in an amount sufficient to enable the mixture to be shaped into the desired form and to retain that form during firing. Generally, the amount of water added may be from 12 to 30 ml for every 100 gm of the dry mixture of the components. The shapeable mixture can then be molded, or extruded to form the desired shape before the shape is fired in a kiln to a maximum temperature of from 1100°C to 1400°C. The temperature in the kiln may be increased at a rate of between 50 to 90°C/hr. and the dwell time at the calcining temperature may be from 1 to 4 hrs before the kiln is allowed to cool to ambient temperatures.

[0051] Where ceramic support elements are produced by an extrusion or a dry-pressing process, they can have an essentially uniform cross-section along one axial direction which provides an axis of symmetry for the element.

[0052] Carriers for catalysts are commonly inorganic materials such as refractory inorganic materials, for example alumina-, silica-, or titania-based compounds, or combinations thereof, such as alumina-silica carriers. Carriers may also be made from carbon-based materials such as, for example, charcoal, activated carbon, or fullerenes.

[0053] Catalytic elements may be made by depositing a catalytically effective amount of one or more catalytically reactive metals on a carrier to make a catalyst precursor. Typically, the carrier is impregnated with metal or compound(s), complex(es) and/or salt(s) sufficient to coat or impregnate the carrier with a catalytically effective amount of catalytically reactive material. As used herein, "catalytically effective amount" means an amount of catalyst that provides a measurable catalytic effect. The impregnated carrier, or catalyst precursor, may be dried in the presence of an atmosphere which also reduces the catalytic material to the corresponding metal.

[0054] Examples of catalytic elements are described, for example, in US Patent Nos. 6,656,874; 6,649,662; 5,952,529; 5,914,432; 5,733,842; 5,512,530; and Published Application 2004/0170556, the disclosures of which are incorporated herein by reference in their entireties.

[0055] The support elements do not need to possess any catalytic activity in that their function is to support the entire weight of the catalyst bed (and any bed limiter present). In one embodiment, the support elements are free or substantially free of catalytic material. In one embodiment, the catalytic activity of the support bed,

measured in terms of the rate of the catalyzed reaction, is less than 20% per unit weight of that of the catalyst bed, in another embodiment, less than 10% per unit weight of that of the catalyst bed, and generally about 1% or less. Where the catalyst bed includes layers of different activity, the activity of the catalyst bed may be considered to be that of the predominant layer (in terms of the weight of catalytic elements) or that of the majority of the elements. For example, if the catalyst bed causes epoxidation of olefins at a rate of 10 moles per minute per kg of catalyst bed, the support bed may catalyze the epoxidation of no more than 1 mole/min./kg of support bed, and generally, less than 0.1 moles /min. For other active beds, the activity of the support bed can be similarly defined in terms of the corresponding activity of the active bed, such as an activity that is less than 20% of the activity of the active bed, per unit weight. For example, if the active bed is provided for sequestering, the support bed may have a sequestering activity of less than 20% of that of the active bed, per unit weight.

[0056] In one embodiment, the support bed **32** does not serve as a catalyst for a reaction of the reagent as it does not have a catalytic material, such as those described in US Patent Nos. 6,656,874; 6,649,662; 5,952,529; 5,914,432; 5,733,842; 5,733,840; 5,512,530; and 2004/0170556 deposited thereon or otherwise incorporated therein. However, it will be appreciated that naturally occurring impurities in the materials used to form the support elements, or the materials themselves, may have some, albeit limited, catalytic activity. Additionally, small amounts of the catalytic material may percolate down through the support bed, over time, giving it some catalytic activity.

[0057] In another embodiment, the support bed **32** is used to support an active bed **36** comprising elements which have little or no catalytic activity, such as sequestering media. The elements of the active bed may be formed from zeolites, silica gels, activated carbon, combinations thereof, and the like.

[0058] Without intending to limit the scope of the invention, the following example demonstrates the effectiveness of one embodiment of the bed support media in reducing the pressure drop and in supporting a catalyst bed.

EXAMPLES

EXAMPLE 1

[0059] Theoretical calculations were made on the pressure drop across a random dumped bed 0.56 m in height of non-porous non-spherical elements constructed according to FIGURE 2 with a diameter D of 19 mm, a length L of 10 mm, and a theoretical void fraction of 60%. Calculations were made for a comparison bed of random dumped non-porous spherical elements of diameter 19 mm and a nominal void fraction of 40%, but otherwise identical to the bed of non-spherical elements. FIGURE 10 shows the pressure drop, in cm water/meter of bed vs. gas mass velocity in kg/hr.m^2 for a bed of the support elements of FIGURE 2. It is apparent that the pressure drop across the bed of spherical elements is higher than for a bed of the present non-spherical elements. In all cases, the pressure drop for the spheres is more than double that of the non-spherical elements. For example, at a gas velocity of 27.9 m/min, the pressure drop for the spheres is about 22.5 cm H_2O/meter, which is at least about five times that of the non-spherical elements having an equivalent diameter (about 4.1 cm H_2O/meter).

EXAMPLE 2

[0060] A mixture of clay, feldspars, and organic extrusion aids comprising about 25% alumina, 68% silica was combined with water. A portion of the mixture was extruded through a die, sectioned into lengths, and fired at a temperature of approximately 1200°C to form bed support elements in two sizes according to the design of FIG 2. The elements have an apparent porosity of less than 0.7%. A first set of the fired elements had a diameter D of about 19 mm and a length L of about 25 mm. A second set of the fired elements had a diameter of about 11 mm and a length L of about 7 mm. A portion of the mixture was used to form two sizes of spheres which were fired to a temperature of approximately 1200°C. The fired spheres had diameters of 19 mm and 6 mm, respectively. Beds of approximately 70 cm in height were formed of the spheres and non-spherical elements, respectively, with the smaller elements placed on top and comprising approximately 23% of the bed height in each case. The void fraction of the bed of non-spherical elements was 60%. The void fraction of the spherical elements was 40%. Actual pressure drop measurements in cm water/ m of bed vs. gas mass velocity in kg/hr.m^2 are shown in FIGURE 11. It is apparent that the pressure drop across the bed of spherical elements was higher than for the equivalent bed of the present non-spherical

elements. In all cases, the pressure drop for the spheres was about double that of the non-spherical elements.

EXAMPLE 3

[0061] Catalyst percolation tests are performed on a bed of the non-spherical support elements formed as described for EXAMPLE 2. A column of catalyst pellets on a bed of support elements is assembled. The support media comprises a layer of about 7.6 cm thick of smaller size support media of diameter D= 11 mm and length L= 7 mm according to the design of FIGURE 2 on top of a layer of about 20 cm thick of larger size support media of D= 25 mm and length L= 11 mm according to the design of FIGURE 2. A layer of about 21 cm thick of 3 mm catalyst pellets is supported on top of this bed. The test involves intense vibration of the column at 3.5 KHz for 10 minutes. The results show that no percolation of the catalyst through the support bed occurs.

[0062] The example embodiment has been described with reference to the preferred embodiments. Obviously, modifications and alterations will occur to others upon reading and understanding the preceding detailed description. It is intended that the example embodiment be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

CLAIMS:

1. A system for treatment of one or more flowing materials comprising:

a shell;

a support bed in the shell comprising a plurality of support elements, the support bed having a void fraction of at least 50%;

an active bed in the shell supported by the support bed; and

wherein the support bed has an activity towards the one or more flowing materials which is less than 20% of that of the active bed on a basis of weight.

2. The system of claim 1, wherein the support bed includes:

a first layer of support elements; and

a second layer of support elements, supported by the first layer, the support elements in the second layer having a smaller size than the support elements in the first layer.

3. The system of claim 1, wherein the activity comprises a catalytic activity and the one or more flowing materials include one or more reactant materials.

4. The system of claim 1, wherein the support elements have an apparent porosity of less than 3%.

5. The system of claim 1, wherein the support elements have an apparent porosity of less than 0.7%.

6. The system of claim 1, wherein the support elements each comprise a generally cylindrical structure with at least one through passage.

7. The system of claim 6, wherein the at least one through passage has a mean width of at least 1 mm.

8. The system of claim 6, wherein the at least one through passage has a mean width which is at least 10% of a maximum width of the support element.

9. The system of claim 6, wherein the support elements comprise a plurality of internal cross members which define the through passages therebetween.

10. The system of claim 9, wherein a first of the internal cross members intersects a second of the internal cross members.

11. The system of claim 6, wherein there are at least four through passages.

12. The system of claim 6, wherein a largest circle which can be enscribed within the through passage has a diameter of less than a diameter of a plurality of active elements in the active bed.

13. The system of claim 12, wherein the diameter of the largest circle is less than 3 mm.

14. The system of claim 1, wherein the support elements each comprise a cross section which is substantially constant along a length of the element.

15. The system of claim 1, wherein the support elements are randomly oriented in the support bed.

16. The system of claim 1, wherein the void fraction is at least 55%.

17. The system of claim 1, wherein the void fraction is less than 80%.

18. The system of claim 1, wherein the void fraction is less than 75%.

19. The system of claim 1, wherein the active bed comprises a plurality of active elements and wherein the support elements comprise at least a lowermost layer of elements in the shell.

20. A system for treatment of one or more flowing materials comprising:

a support bed comprising a plurality of non-spherical support elements, the support elements each defining at least one through passage; and

a bed comprising a plurality of active elements supported by the support bed, the support elements having an activity per unit weight towards the flowing materials which is no greater than 20% of the activity per unit weight of a majority of the active elements in the bed of active elements. The system of claim 20, wherein the void fraction of the support bed is at least 45%.

21. The system of claim 20, wherein the void fraction is at least 50%.

22. A system for treatment of a fluid material comprising:

a shell having a base at a lower end thereof and an inlet and an outlet for the fluid material;

a column of elements within the shell through which the fluid material passes, the column comprising:

a support bed of elements, the support bed comprising the elements of the column closest to the base, the support bed having a void fraction of at least 50%; and

an active bed of elements supported by the support bed for treatment of the fluid material.

23. The system of claim 22, wherein the elements in the active bed have a greater activity toward the fluid material than the discrete elements in the support bed.

24. The system of claim 22, wherein the inlet is positioned in the lower end of the shell.

25. The system of claim 22, wherein the outlet is positioned in the lower end of the shell.

26. A system for treatment of a fluid material comprising:

a shell having a base at a lower end thereof and an inlet and outlet, one of the inlet and the outlet being closer to the base than the other of the inlet and outlet;

a column of elements within the shell through which the fluid material passes between the inlet and the outlet, the column comprising:

an active bed of active elements for treatment of the fluid material; and

a support bed which supports the active bed thereon, the support bed comprising a plurality of elements each having at least one through passage, the support bed including those elements of the column that are closest to the one of the inlet and outlet that is closer to the base, the support bed having a void fraction of at least 45%.

27. A method of forming a system for treatment of a flowing material comprising:

placing a plurality of support elements in a column to form a support bed, the support bed having a void fraction of at least 50% including forming a layer of the support bed which defines a lowermost layer of elements in the column; and

supporting a bed of active elements on the support bed.

28. A method treating one or more flowing materials using the system **of claim 1**, comprising:

flowing one or more materials through the active bed.

29. The method of claim 28, further comprising:

maintaining an average support bed pressure drop ratio of less than 9:10 during the entire flowing step, wherein the support bed pressure drop ratio is the ratio of the pressure drop across the support bed using the support elements to the expected pressure drop across a support bed using equivalently-sized spherical support elements.

30. The method of claim 29, wherein the pressure drop ratio is less than 8:10.

31. The method of claim 30, wherein the pressure drop ratio is less than about 1:2.

32. A method treating one or more fluids using the system **of claim 22**, comprising:

flowing one or more materials through the active bed.

33. The method of claim 32, wherein the flowing comprises:

maintaining an average support bed pressure drop ratio of less than 1:2 during the flowing step, wherein the support bed pressure drop ratio is the ratio of the pressure drop across the support bed using the support elements to the expected pressure drop across a support bed using equivalently-sized spherical support elements.