EUROPEAN PATENT SPECIFICATION

Cross-flow filtration device with increasing thickness walls
Querstromfiltervorrichtung mit Wänden mit zunehmender Stärke
Dispositif de filtration à courant transversal avec des parois avec épaisseur augmentante

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Remarks:
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Description

[0001] This invention relates to an improved cross-flow filtration or membrane device for separating a feed stock into filtrate and retentate, and more particularly to such a device having a matrix of porous walls defining a plurality of constant hydraulic diameter cells exhibiting an increasing aggregate wall thickness as the cells advance in at least one direction from the central perpendicular axis to the peripheral surface.

BACKGROUND OF THE INVENTION

[0002] There are a multitude of filtration devices which separate a feed stock into filtrate and retained suspended matter which is too large to pass through the pore structures of the filter. A straight-through filter retains the suspended matter on the filter surface or within the filter matrix and passes only the filtrate. Cross-flow filters operate with tangential flow across the filter surface to sweep away suspended matter unable to pass through the filter surface pores. Cross-flow filters provide for the continuous extraction of retentate, or concentrated suspended matter, from one portion of the device and continuous extraction of filtrate from another portion.

[0003] Cross-flow filters can be constructed using multiple passageway, porous monoliths. Such monoliths can have tens of thousands of passageways extending through them, with the passageways normally parallel and uniformly spaced. When in use the feedstock is introduced under pressure at one end of the monolith, flows in parallel through the passageways, and a portion is withdrawn as retentate at the downstream end of the device, while a second portion passes through the membrane and porous monolith walls to exit at the periphery of the monolith.

[0004] Filtrate which passes into the porous monolith walls separating the passageways combines and flows through the walls toward the periphery of the monolith, and is removed through the outer skin of the monolith. The resistance to flow in the tortuous flow path of the monolith passageway walls can severely limit filtration capacity, and for this reason cross-flow filters based on large diameter high surface area, multiple passageway, porous monoliths are not found in wide commercial use.

[0005] Membrane devices utilize a semipermeable membrane to separate filtrate, also called permeate, from retentate. There is a multitude of different pressure driven membrane devices which separate and concentrate particles, colloids, macromolecules, and low molecular weight molecules. Membranes generally require a mechanical support which can be integral with the membrane, or separate. For example, membranes can be coated onto, or simply mechanically supported by, a porous support material.

[0006] Multiple-passageway, porous monoliths, e.g., honeycomb substrates, can be especially useful as membrane supports. In this instance membranes are applied to the passageway walls, which serve as both a mechanical support and as the flow path for filtrate removal to a filtrate collection zone. The walls of the substrate not only act as the supports for the membranes, but also serve as the egress path for the filtrate or permeate. In these pressure driven separation processes, the feed is forced through the small pores of the membranes that are supported on the walls of the honeycomb. Once the fluid has passed through the small pore size of the membranes (the path of most resistance), the filtered material enters the relatively larger pore of the walls. The amount of filtrate material that can pass from the innermost cell or cells, to the outside of the substrate, is limited by the wall porosity and thickness. If the walls are not sufficiently thick or sufficiently porous, the total volume of filtrate cannot be carried through the walls to the skin, and hence to the outside of the substrate. This results in a failure to use all of the available membrane surface area. That is, all or most of the feed that passes through the innermost cell or cells may simply pass through the support as retentate, without any portion passing through the membranes supported on those cells.

SUMMARY OF THE INVENTION

[0007] Accordingly, the present invention described herein is a cross-flow filtration device for receiving a feed stock and for separating the feed stock into filtrate and retentate, comprising:

a multicellular monolith structure having a central longitudinal axis and a peripheral surface and having inlet and outlet end faces and a matrix of porous walls defining a plurality of cells extending longitudinally and mutually parallel therethrough between the inlet and outlet end faces,

each of the cells exhibiting a constant hydraulic diameter, a uniform transverse cross section throughout their length and a varying cross-section and shape when compared to at least one other cell;

the cells, advancing in at least one direction from the central longitudinal axis towards the peripheral surface, exhibiting an increasing total combined wall thickness of the walls defining each cell.

[0008] This design overcomes the aforementioned flow problems and allows all of the filtrate volume to be carried through the porous walls to the outer surface of the filter device.
One embodiment of the filtration device comprises a cylindrical monolith structure having a matrix of radially-extending and circumferential porous walls. The radially extending walls exhibit an increasing thickness as measured from the central longitudinal axis towards the peripheral surface. Each successive circumferential wall exhibits an increased thickness as the walls advance from the central longitudinal axis towards the peripheral surface.

One essential advantage of this inventive filtration device possessing the "increasing aggregate wall thickness" concept is that the walls of the honeycomb structure are able to accommodate the permeate flow from all of the cells of the support, and in return all the available membrane surface area is used. Furthermore, the constant hydraulic diameter characteristic assures that each cell carries an equivalent volume of feedstock thereby ensuring that all of the available membrane surface area will be fully utilized; ultimately, a filtration device of increased efficiency.

**BRIEF DESCRIPTION OF THE FIGURES**

**FIG. 1** illustrates a cross section through a square embodiment of the inventive filtration device.

**FIG. 2** illustrates a cross section through another square embodiment of the inventive filtration device.

**FIG. 3** illustrates a cross section through a circular embodiment of the inventive filtration device.

**DETAILED DESCRIPTION OF THE INVENTION**

Referring now to FIG. 1, the present invention is generally directed at a cross-flow filtration device for receiving a feed stock and for separating the feed stock into filtrate and retentate. The filtration device comprises a multicellular monolith structure 10, a rectangular structure in this embodiment, possessing both an inlet and outlet end face, one of which is shown, and having a central longitudinal axis 11 and a peripheral surface 12, the axis 11 defined as the axis perpendicular to the plane formed by, and running through the intersection of, the x and y axis as shown in FIG. 1. The structure possesses a matrix of porous walls defining a plurality of cells 20 extending longitudinally and mutually parallel therethrough. Each of the cells 20, exhibits a constant hydraulic diameter, a uniform transverse cross section throughout their length and a varying cross-section and shape when compared to at least one other cell, i.e. a different cross-section and shape to at least one other cell.

The hydraulic diameter of any conduit such as a cell, whether carrying a liquid or gas, is defined as four times the transverse cross-sectional area divided by the wetted or contacted perimeter of the opening. Stated another way -- two differently shaped cylinders will exhibit the same resistance to flow through them (liquid or gas), if they exhibit the same hydraulic diameter.

Furthermore, as cells 20 advance in at least one direction from the central longitudinal axis to the peripheral surface they exhibit an increasing "aggregate wall thickness" i.e., the total combined thickness of the four walls which define each cell 20 in the structure depicted in FIG. 1 it can be seen that there is an increase in the aggregate wall thickness for the cells which advance in all directions, from the central longitudinal axis to the peripheral surfaces except for the direction which is directly along the y-axis. For example, the aggregate wall thickness of central longitudinal axis-proximate cell designated 20 A - combined thickness of walls 21, 22, 23 and 24, is less than intermediate cell designated 20 B - combined thickness of walls 21, 22, 25, 26, which is less then peripherally-proximate cell designated 20 C - combined thickness of walls 21,22,27, 28.

Referring now to FIG. 2, shown is another embodiment of a filtration device comprising a multicellular monolith square structure 30, possessing both an inlet and outlet end face, one of which is shown, and having a central longitudinal axis 31 and a peripheral surface 32; the axis 31 defined as the axis perpendicular to the plane formed by, and running through the intersection of the x and y axis as shown in FIG. 2 Again, the structure possesses a matrix of porous walls defining a plurality of cells extending longitudinally and mutually parallel therethrough. As described above, each of the cells, 41-44 exhibits a constant hydraulic diameter, a uniform transverse cross section throughout their length and a varying cross-section and shape when compared to at least one of the other cells; specifically, the cells having four distinctive shapes 41, 42, 43 and 44.

The embodiment depicted in FIG. 2 differs from the embodiment illustrated in FIG.1 in that as cells 41-44 advance in all directions from the central longitudinal axis 31 to the peripheral surface 32 they exhibit an increasing "aggregate wall thickness". For example, the aggregate wall thickness of cell 41, proximate to the central longitudinal axis - combined thickness of walls 45Y, 46Y, 45X and 46X defining cell 41, is less than the aggregate cell thickness of the following three cells: (1) cell 41 proximate the peripheral surface 32 - combined thickness of walls 47X, 48X, 47Y and 48Y defining cell 41, (2) cell 44 proximate the peripheral surface 32 and located along the X-axis - combined thickness of walls 45X, 46X, 47Y and 48Y defining cell 44; and, (3) cell 44 proximate the peripheral surface and located along the Y-axis - combined thickness of walls 45Y, 46Y, 47X and 48X defining cell 44.

Referring now to FIG.3, depicted therein is another embodiment of the filtration device comprised of a cylindrical and multicellular monolith structure 99 which has a central longitudinal axis 51 and a peripheral surface 52. The monolith structure 99 possesses a matrix of radially extending 66 and circumferential 61-65 porous walls which define...
a plurality of cells. Numerals 50, 60, 70, 80 and 90 each designates a ring or zone of cells: (1) 50 denotes the central longitudinal axis 51 cell zone and comprises one circular cell 50 designated the Zone AA cell; (2) 60 denotes the radially innermost zone of cells 55, designated Zone A cells, while 70 indicates a next radially innermost zone of cells 72, designated Zone B cells; and, (3) 90 denotes the radially outermost zone of cells 92, designated Zone D cells, while 80 designates a zone of cells 82 inside the Zone D cells, designated Zone C cells.

[0020] Again, each of the cells 50,55,72,82,92, exhibits a uniform transverse cross section throughout their length, are mutually parallel and extend longitudinally through and between the inlet and outlet end faces of the structure 99. Furthermore, the cross sectional area and shape of each of the cells 50,55,72,82,92, is varied such that they all exhibit a constant hydraulic diameter as defined above.

[0021] The radially-extending walls 66 exhibit an increasing thickness, as measured from the central longitudinal axis 51 towards the peripheral surface 52. Each successive circumferential wall exhibits an increased thickness over that circumferential cell wall adjacent to it and located closer to the central longitudinal axis 51, e.g., circumferential wall 62 exhibits an increased thickness over that thickness exhibited by circumferential wall 61. Specifically, the cell walls 61-65 which separate each of the cell zones AA-D (Zone D and the peripheral surface at the outer extreme) increase in thickness. Stated in another way, the thickness increases as the cell walls 66 advance from the central perpendicular axis cell 50 wall 61 to the cell wall 65 located between the peripheral wall 52 and the Zone D cells 92.

[0022] The cross-flow filtration devices described above can be fabricated from a variety of porous materials including materials such as glass, ceramics, glass-ceramics, organic polymers, metals, activated carbon and mixtures thereof. Ceramic materials that are especially suitable include those made of cordierite, mullite, clay, talc, zinc, zirconia, zirconates, zirconia-spinel, magnesium alumino-silicates, spinel, alumina, silica, silicates, borides, aluminosilicates, such as, zeolites, porcelain, lithium alumino-silicates, alumina silica, feldspar, titania, fused silica, nitrides, borides, carbides, such as, silicon carbide, silicon nitride, or mixtures thereof. For those applications where a very fine pore size is desired, the preferred material is selected from the group consisting of mullite, alumina and titania.

[0023] The monolith structure which forms the filtration device should be formed such that it exhibits a high volume porosity, i.e., a porosity ranging from about 25%-50%, by volume. Additionally, if the monolith structure is to be used in ultrafiltration or microfiltration applications it should possess a relatively large average pore diameter of between about 0.1-10 micrometers; preferably exhibiting an average pore diameter of between about 0.1-5 micrometers. If, on the other hand, the filtration device is to be used in gas separation applications it is desirable that the monolith structure exhibit an average pore diameter of between about 0.1-2 micrometers.

[0024] Permselctive membranes, selected from the membranes suitable for cross-flow filtration, microfiltration, ultrafiltration, reverse osmosis, gas separations, pervaporation may be applied to the surface of the cells of the aforementioned monolith structure.

[0025] For fabrication of the monolith structure as illustrated in FIG. 3, the die as described in U.S. Pat. No. 4,979,889, (Frost et al.) is especially useful. Briefly, the die disclosed therein is comprised of a plurality of rigid tubes, each slotted along a portion of its length and each provided, at the die input face, with an integral, radially extending collar. Each collar has a plurality of extending notches uniformly angularly disposed around its periphery, each collar being of different longitudinal thickness and nesting within a counterbore in its next radially outward neighboring or adjacent collar. A plurality of angularly spaced slots run partially longitudinally by each tube. Each slot extends through its respective tube wall, the exterior surface of each tube, except for the radially outermost tube, which is radially spaced from the interior surface of the next adjacent radial outer tube. A rigid holder has a central bore which runs longitudinally through it, the holder opening has a counterbore at an end which receives the radially outermost collar. The bore of the holder is radially spaced from the exterior of the outermost, whereby a plurality of passageways is defined for the passage of an extrudable substance from the notches on the collars to the noncollared ends of the tubes. Lastly, the material to be extruded from the die, to form the monolith structure described herein, is fed into the openings defined by the collar notches and is extruded from the output of downstream ends of the slots in the tubes.

EXAMPLES

Example 1

[0026] A square monolith structure possessing 15.01 cm (5.91 in.) side dimension, exhibiting the cell and wall configuration as illustrated in FIG. 2 and the cell centerline location dimensions indicated as $x_1$-$x_5$ and $y_1$-$y_5$ in FIG. 2 and as reported in Table I (in centimetres with inches in brackets), would be suitable for use as a filtration device or as membrane support. Specifically, the structure would exhibit four distinctive cells shapes/sizes, cell designations 41,42,43, and 44, all exhibiting a hydraulic diameter of 1.02 cm (0.40 in.) and possessing the following dimensions: (1) cell 41 - 1.02 x 1.02 cm (0.4 x 0.4 in.); (2) cell 42 - 1.12 x 0.98 cm (0.44 x 0.386 in.); (3) cell 43 - 1.27 x 0.85 cm (0.501 x 0.333 in.); and (4) cell 44 - 1.64 x 0.74 cm (0.645 x 0.291 in.).

[0027] Utilizing the cell centerline location dimensions and the aforementioned cell sizes enables the calculation of
the aggregate wall thickness for any desired cell. The aggregate wall thickness of cell 41, proximate to the central longitudinal axis - combined thickness of walls 45Y, 46Y, 45X and 46X of 2.04 cm (0.8 in.), is less than the aggregate wall thickness of the following three aforementioned cells: (1) cell 41 defined by walls 47X, 48X, 47Y and 48Y - 3.74 cm (1.472 in.); (2) cell 44 defined by walls 45X, 46X, 47Y and 48Y - 2.65 cm (1.0415 in.); and, (3) cell 44 defined by walls 45Y, 46Y, 47X and 48X - 2.65 cm (1.0415 in.).

Example 2

[0028] A monolith structure exhibiting a cell and wall configuration as illustrated in FIG 3 and exhibiting the dimensions reported in TABLE II would be suitable for use as a filtration device or as membrane support. The structure would exhibit the following dimensions: an approximate diameter of 2.70 cm (1.06 in.), a variable axial length, e.g. approximately 90 cm (36 in.), an approximate cell density of 12 cells/cm² (78 cells/in²), an open porosity of approximately 43% and a constant hydraulic cell diameter of 1.90 cm (0.75 in.). Specifically, TABLE II reports the following additional hypothetical dimensions: (1) the hypothetical thickness calculated for the radially extending wall at various locations as the wall extends to the peripheral wall - specifically measured at each of the cell zones A-D as described above; and, (2) the hypothetical calculated thicknesses of the successive circumferential walls as they approach the peripheral wall. An examination of the table reveals that the monolith structure formed with these dimensions would exhibit the inventive features of (1) a radial extending wall which exhibits an increasing thickness as measured from the central longitudinal axis; and, (2) successive circumferential walls exhibiting an increasing thickness as the peripheral wall is approached. Specifically, the table reports that the circumferential walls' thicknesses increases from 0.508 to 1.27 mm (0.02 to 0.05 in.), while the radial wall also exhibited the same increase in thickness increase from 0.508 to 1.27 mm (0.02 to 0.05 in.).

TABLE II

<table>
<thead>
<tr>
<th>Measurement Location</th>
<th>Radial Wall Thickness</th>
<th>Circumferential Wall</th>
<th>Wall Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone A cells</td>
<td>0.02 in/0.508 mm</td>
<td>Cen. axis-A</td>
<td>0.020/0.508 mm</td>
</tr>
<tr>
<td>Zone B cells</td>
<td>0.03 in/0.762 mm</td>
<td>A-B</td>
<td>0.025 in/0.635 mm</td>
</tr>
<tr>
<td>Zone C cells</td>
<td>0.04 in/1.016 mm</td>
<td>B-C</td>
<td>0.035 in/0.889 mm</td>
</tr>
<tr>
<td>Zone D cells</td>
<td>0.05 in/1.27 mm</td>
<td>C-D</td>
<td>0.045 in/1.143 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D-periph. wall</td>
<td>0.05 in/1.27 mm</td>
</tr>
</tbody>
</table>

[0029] Although four-walled cells are described above, cell shapes other than these, such as round or triangular, etc. may be employed.

Claims

1. A cross-flow filtration device for receiving a feed stock and for separating the feed stock into filtrate and retentate, comprising:

   a multicellular monolith structure (10) having a central longitudinal axis (11) and a peripheral surface (12) and having inlet and outlet end faces and a matrix of porous walls defining a plurality of cells (20) extending longitudinally and mutually parallel therethrough between the inlet and outlet end faces, each of the cells (20) exhibiting a constant hydraulic diameter, a uniform transverse cross section throughout their length and a varying cross-section and shape when compared to at least one other cell; the cells, (20) advancing in at least one direction from the central longitudinal axis towards the peripheral surface, exhibiting an increasing total combined wall thickness of the walls defining each cell.
2. A cross-flow filtration device according to claim 1, wherein a permselective membrane is applied to the surface of said cells (20).

3. A cross-flow filtration device according to claim 1 or 2 wherein cells (20) advancing in all directions from the central longitudinal axis (11) towards the peripheral surface (12) exhibit an increasing total combined wall thickness of the walls defining each cell.

4. A cross-flow filtration device according to claim 1 or 2 wherein the monolith structure (10) is cylindrical and comprised of a matrix of radially-extending (66) and circumferential porous walls (61, 62, 63, 64, 65) with each of the radially-extending walls (66) exhibiting an increasing total combined wall thickness of the walls defining each cell, as measured from the central longitudinal axis (11) towards the peripheral surface (12) and each successive circumferential wall (61, 62, 63, 64, 65) exhibiting an increased total combined wall thickness of the walls defining each cell as the walls advance from the central longitudinal axis (11) towards the peripheral surface (12).

5. A cross-flow filtration device according to claim 1 or 2 wherein the monolith structure (10) exhibits a volume porosity ranging from about 25%-50%.

6. A cross-flow filtration device according to claim 1 or 2 wherein the monolith structure (10) exhibits an average pore diameter of between about 0.1-10 micrometers.

7. A cross-flow filtration device according to claim 1 or 2 wherein the monolith structure (10) exhibits an average pore diameter of between about 0.1-5 micrometers, or between about 0.1-2 micrometers.

8. A cross-flow filtration device according to claim 1 or 2 wherein the monolith structure (10) is comprised of glass, ceramic, glass-ceramic, organic polymer, metal, activated carbon or mixtures thereof.

9. A cross-flow filtration device according to claim 8 wherein the monolith is a ceramic selected from the group consisting of cordierite, mullite, clay, talc, zircon, zirconia, zirconates, zirconia-spinel, magnesium alumino-silicates, spinel, alumina, silica, silicates, borides, alumino-silicates, such as, porcelains, zeolites, lithium alumino-silicates, alumina silica, feldspar, titania, fused silica, nitrides, borides, carbides, such as, silicon carbide, silicon nitride, or mixtures thereof.

10. A cross-flow filtration device according to claim 1 or 2 having a permselective membrane selected from the group consisting of membranes suitable for cross-flow filtration, microfiltration, ultrafiltration, reverse osmosis, gas separations, and pervaporation.

Patentansprüche

1. Querstromfiltrierung zur Aufnahme eines zugeführten Gutes und zur Trennung des zugeführten Gutes in Filtrat und Rückstand, mit:

   einem vielzelligen monolithischen Aufbau (10), der eine zentrale Längsachse (11) und eine Umfangsfläche (12) sowie Einlass- und Auslassendflächen und eine Matrix an porösen Wänden aufweist, die zahlreiche Zellen (20) bilden, welche sich in Längsrichtung und wechselseitig parallel zwischen den Einlass- und Auslassendflächen hindurch erstrecken,

   wobei jede der Zellen (20) einen konstanten Flüssigkeitsdurchmesser, einen gleichförmigen Querschnittsabchnitt durch ihre Länge und einen varierenden Querschnitt und eine varierende Form im Vergleich mit wenigstens einer anderen Zelle aufweist;

   wobei die Zellen (20), die in wenigstens einer Richtung von der zentralen Längsachse zu der Umfangsfläche fortschreiten, eine zunehmende Gesamtwanddicke der jede Zelle bildenden Wände aufweisen.

2. Querstromfiltrierung nach Anspruch 1, bei der auf die Oberfläche der Zellen (20) eine permselective Membran aufgebracht ist.

3. Querstromfiltrierung nach Anspruch 1 oder 2, bei der die Zellen (20), die in allen Richtungen von der zentralen
Längsachse (11) zu der Umfangsfläche (12) fortschreiten, eine zunehmende kombinierte Gesamtwanddicke der Wände, die jede Zelle bilden, aufweisen.

4. Querstromfiltrvorrichtung nach Anspruch 1 oder 2, bei der der monolithische Aufbau (10) zylindrisch ist und eine Matrix aus sich in radialer Richtung erstreckenden (6) und im Umfang poröse Wänden (61, 62, 63, 64, 65) aufweist, wobei jede der sich radial erstreckenden Wände (66) eine zunehmende zusammengesetzte Gesamtwanddicke der jede Zelle bildenden Wände aufweist, gemessen von der zentralen Längsachse (11) zu der Umfangsfläche (12), und wobei jede anschließende Umfangswand (61, 62, 63, 64, 65) eine zunehmende kombinierte Gesamtwanddicke der jede Zelle bildenden Wände beim Fortschreiten der Wände von der zentralen Längsachse (11) zu der Umfangsfläche (12) aufweist.

5. Querstromfiltrvorrichtung nach Anspruch 1 oder 2, bei der der monolithische Aufbau (10) eine Volumenporosität aufweist, die von etwa 25% bis 50% reicht.

6. Querstromfiltrvorrichtung nach Anspruch 1 oder 2, bei der der monolithische Aufbau (10) einen durchschnittlichen Porendurchmesser zwischen etwa 0,1 - 10 \(\mu m\) aufweist.

7. Querstromfiltrvorrichtung nach Anspruch 1 oder 2, bei der der monolithische Aufbau (10) einen durchschnittlichen Porendurchmesser zwischen 0,1 - 5 \(\mu m\) oder zwischen etwa 0,1 - 2 \(\mu m\) aufweist.

8. Querstromfiltrvorrichtung nach Anspruch 1 oder 2, bei der der monolithische Aufbau (10) aus Glas, Keramik, Glaskeramik, organischem Polymer, Metall, Aktivkohle oder Mischung derselben besteht.


10. Querstromfiltrvorrichtung nach Anspruch 1 oder 2, mit einer permselektiven Membran, die der Gruppe ausgewählt ist, die aus Membranen besteht, welche für Querstromfiltration, Mikrofiltration, Ultrafiltration, Umkehrosmose, Gastrennung und Verdunstung geeignet sind.

**Revendications**

1. Dispositif de filtration en courant transversal pour recevoir une charge d'alimentation et pour séparer la charge d'alimentation en un filtrat et un rétentat, comprenant:
   - une structure monolithe multicellulaire (10) ayant un axe longitudinal central (11) et une surface périphérique (12) et ayant des faces terminales d'entrée et de sortie et une matrice de parois poreuses définissant une pluralité de cellules (20) s'étendant longitudinalement et mutuellement parallèles à travers celle-ci entre les faces terminales d'entrée et de sortie,
   - chacune des cellules (20) présentant un diamètre hydraulique constant, une section transversale uniforme sur l'ensemble de leur longueur et une section transversale et une forme variables lorsqu'elle est comparée à au moins une autre cellule;
   - les cellules (20) avançant dans au moins une direction depuis l'axe longitudinal central et vers la surface périphérique, présentant une épaisseur de paroi combinée totale croissante des parois définissant chaque cellule.

2. Dispositif de filtration en courant transversal selon la revendication 1, dans lequel une membrane permselective est appliquée à la surface desdites cellules (20).

3. Dispositif de filtration en courant transversal selon la revendication 1 ou 2, dans lequel des cellules (20) avançant dans toutes les directions depuis l'axe longitudinal central (11) vers la surface périphérique (12) présentent une épaisseur de paroi combinée totale croissante des parois définissant chaque cellule.

4. Dispositif de filtration en courant transversal selon la revendication 1 ou 2, dans lequel la structure monolithe (10) est cylindrique et est constituée d'une matrice de parois poreuses s'étendant radialement (66) et de parois poreuses...
circonférentielles (61, 62, 63, 64, 65) avec chacune des parois s’étendant radialement (66) présentant une épaisseur de paroi combinée totale croissante des parois définissant chaque cellule, tel que mesuré à partir de l’axe longitudinal central (11) vers la surface périphérique (12) et chaque paroi circonférentielle successive (61, 62, 63, 64, 65) présentant une épaisseur de paroi combinée totale croissante des parois définissant chaque cellule à mesure que les parois avancent depuis l’axe longitudinal central (11) vers la surface périphérique (12).

5. Dispositif de filtration en courant transversal selon la revendication 1 ou 2, dans lequel la structure monolithe (10) présente une porosité volumique variant d’environ 25% à 50%.

6. Dispositif de filtration en courant transversal selon la revendication 1 ou 2, dans lequel la structure monolithe (10) présente un diamètre de pores moyen compris entre environ 0,1 et 10 micromètres.

7. Dispositif de filtration en courant transversal selon la revendication 1 ou 2, dans lequel la structure monolithe (10) présente un diamètre de pores moyen compris entre environ 0,1 et 5 micromètres, ou entre environ 0,1 et 2 micromètres.

8. Dispositif de filtration en courant transversal selon la revendication 1 ou 2, dans lequel la structure monolithe (10) est constituée de verre, de céramique, de verre-céramique, de polymère organique, de métal, de charbon actif ou d’un mélange de ceux-ci.

9. Dispositif de filtration en courant transversal selon la revendication 8, dans lequel le monolithe est une céramique choisie parmi le groupe constitué par la cordiérite, la mullite, l’argile, le talc, le zircon, la zirconite, les zirconates, la zircone-spinelle, les alumino-silicates de magnésium, la spinelle, l’alumine, la silice, les silicates, les borures, les alumino-silicates, tels que les porcelaines, les zéolithes, les alumino-silicates de lithium, la silice alumine, le feldspath, le dioxyde de titane, la silice fondu, les nitrures, les borures, les carbures, tels que le carbure de silicium, le nitrure de silicium, ou des mélanges de ceux-ci.

10. Dispositif de filtration en courant transversal selon la revendication 1 ou 2, ayant une membrane perméable choisie parmi le groupe constitué par les membranes convenant pour la filtration en courant transversal, la microfiltration, l’ultrafiltration, l’osmose inverse, la séparation des gaz, et la pervaporation.