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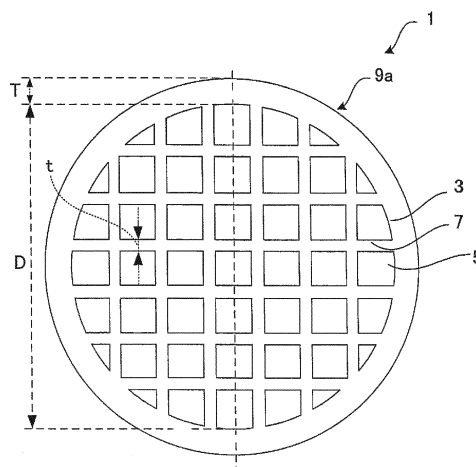
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(54) **HEAT EXCHANGING MEMBER**

(57) The present invention aims at providing a technique for inhibiting the breakage due to thermal stress while maintaining temperature efficiency and corrosion resistance. There is provided a heat exchanger element 1 having a cylindrical outer peripheral wall 3 and partition walls 7 which are made of ceramic containing SiC as a main component and separate and form a plurality of cells 5 functioning as passages for a first fluid inside the outer peripheral wall 3. More specifically, in the heat exchanger element 1, the outer peripheral wall 3 and the

partition walls 7 mediate heat exchange between the first fluid and the second fluid, and the thickness T of the outer peripheral wall 3, the equivalent circle diameter D calculated from the area of the portion inside the outer peripheral wall 3 in a cross section perpendicular to an axial direction of the outer peripheral wall 3, and thickness t of the partition walls 7 satisfy the following formulae (1) to (3): Formula (1): $0.3 \text{ mm} \leq T \leq 4.0 \text{ mm}$, Formula (2): $15 \text{ mm} \leq D \leq 120 \text{ mm}$, and Formula (3): $0.04 \times T \leq t \leq 0.6 \text{ mm}$.

FIG.2



Description

Technical Field

5 **[0001]** The present invention relates to a heat exchanger element fixed to a heat exchanger for use.

Background Art

10 **[0002]** A heat exchanger is sometimes used when a fluid (gas, liquid) is heated or cooled. In a heat exchanger, a high-temperature fluid and a low temperature fluid is separated from each other by a passage wall having thermal conductivity, and heat is transferred to the passage wall, thereby conducting heat exchange between both the fluids. In such a heat exchanger, if the area of the passage wall separating the high-temperature fluid from the low-temperature fluid is widened, the efficiency of heat exchange can be improved. Therefore, in order to widen the area of the passage wall, there has been devised a heat exchanger having a structure where a high-temperature fluid and a low temperature fluid are separated from each other by the corrugated passage wall. In addition, for a similar purpose, there has been devised a heat exchanger having a structure where each of the passage for a high-temperature fluid and the passage for a low-temperature fluid is divided into a plurality of passages and arranged so that the divided high-temperature passages and low-temperature passages are alternately disposed.

15 **[0003]** In such a heat exchanger, since the passage walls are constantly exposed to the fluid, the passage walls are at risk of corrosion depending on the properties of the fluid. Therefore, for a heat exchanger, there has been proposed a technique of enhancing corrosion resistance by the use of ceramic passage walls (e.g., Patent Document 1).

Prior Art Document

25 Patent Document

[0004] Patent Document 1: JP-A-61-24997

Summary of the Invention

30 **[0005]** However, in the proposed technique, contraction or expansion is caused (thermal stress is generated) when ceramic passage walls receive heat, and the passage walls may be at risk of breakage due to the thermal stress. In particular, mixture of a high-temperature fluid and a low-temperature fluid due to the breakage of the passage walls impairs the function as a heat exchanger.

35 **[0006]** In view of the aforementioned problems, the present invention aims at providing a technique for inhibiting the breakage due to thermal stress while maintaining temperature efficiency and corrosion resistance.

[0007] The present invention is the heat exchanger element shown below.

40 **[0008]** [1] A heat exchanger element comprising: a cylindrical outer peripheral wall made of ceramic containing SiC as a main component, and partition walls which are made of ceramic containing SiC as a main component and separate and form a plurality of cells functioning as passages for a first fluid in a portion inside the outer peripheral wall; wherein the outer peripheral wall and the partition walls mediate heat exchange between the first fluid flowing through the portion inside the outer peripheral wall and the second fluid flowing the portion outside the outer peripheral wall, and the thickness T of the outer peripheral wall, the equivalent circle diameter D calculated from the area of the portion inside the outer peripheral wall in a cross section perpendicular to an axial direction of the outer peripheral wall, and thickness t of the partition walls satisfy the following formulae (1) to (3):

$$\text{Formula (1): } 0.3 \text{ mm} \leq T \leq 4.0 \text{ mm}$$

50

$$\text{Formula (2): } 15 \text{ mm} \leq D \leq 120 \text{ mm}$$

55

$$\text{Formula (3): } 0.04 \times T \leq t \leq 0.6 \text{ mm}$$

[0009] [2] The heat exchanger element according to the above [1], wherein the thickness T of the outer peripheral wall, the equivalent circle diameter D calculated from the area of the portion inside the outer peripheral wall in a cross

section perpendicular to an axial direction of the outer peripheral wall, and thickness t of the partition walls satisfy the following formulae (4) to (6):

$$\text{Formula (4): } 0.5 \text{ mm} \leq T \leq 4.0 \text{ mm}$$

$$\text{Formula (5): } 30 \text{ mm} \leq D \leq 60 \text{ mm}$$

$$\text{Formula (6): } 0.04 \times T \leq t \leq 0.6 \text{ mm}$$

[0010] [3] The heat exchanger element according to the above [1] or [2], wherein a cross sectional shape of the cells is a polygon constituted of obtuse angles.

[0011] [4] The heat exchanger element according to any one of the above [1] to [3], wherein at least one of the outer peripheral wall and the partition walls is dense.

[0012] [5] The heat exchanger element according to any one of the above [1] to [4], which has a covering member provided to separate the first fluid from the second fluid and covering the outer peripheral wall so as to be able to exchange heat between the first fluid and the second fluid.

[0013] According to a heat exchanger element of the present invention, breakage due to thermal stress can be inhibited while maintaining temperature efficiency and corrosion resistance.

Brief Description of the Drawings

[0014]

[Fig. 1] Fig. 1 is a perspective view of an embodiment of a heat exchanger element of the present invention.

[Fig. 2] Fig. 2 is a front view of the heat exchanger element shown in Fig. 1, viewed from one end portion side.

[Fig. 3] Fig. 3 is a schematic view of a heat exchanger having the heat exchanger element of Fig. 1 fixed thereto.

[Fig. 4] Fig. 4 is a cross-sectional view along A-A' of Fig. 3.

[Fig. 5] Fig. 5 is a cross-sectional view along B-B' of Fig. 3.

[Fig. 6] Fig. 6 is a perspective view of a modified example of an embodiment of a heat exchanger element of the present invention.

[Fig. 7] Fig. 7 is a perspective view of another modified example of an embodiment of a heat exchanger element of the present invention.

[Fig. 8] Fig. 8 is an enlarged view of one end portion of a heat exchanger element having cells having a hexagonal cross-sectional shape.

[Fig. 9] Fig. 9 is an enlarged view of one end portion of a heat exchanger element having a notch in the partition walls.

[Fig. 10] Fig. 10 is an enlarged view of a part of a cross section of a heat exchanger element having a notch in the outer peripheral wall.

[Fig. 11] Fig. 11 is an enlarged view of a part of a cross section of a heat exchanger element having different thickness of the partition walls between the center side and the outer periphery side.

Mode for Carrying out the Invention

[0015] Hereinbelow, an embodiment of the present invention will be described. The present invention is not limited to the following embodiment, and changes, modifications, and improvements may be made as long as they do not deviate from the scope of the present invention.

[0016] A heat exchanger element of the present invention has a cylindrical outer peripheral wall made of ceramic containing SiC as the main component and partition walls which are made of ceramic containing SiC as the main component and separate and form a plurality of cells functioning as passages for the first fluid inside the outer peripheral wall.

[0017] In a heat exchanger element of the present invention, in the case of allowing the first fluid to flow through the portion inside the outer peripheral wall and the second fluid to flow through the portion outside the outer peripheral wall, the outer peripheral wall and the partition walls mediate heat exchange between the first fluid and the second fluid.

[0018] In a heat exchanger element of the present invention, the first fluid is divided and sent into a plurality of cells. By dividing the first fluid and sending into each of the cells, the first fluid can flow while being brought into contact with

the partition walls surrounding each cell. As a result, heat exchange can be performed between the first fluid and the partition walls. Further, by means of heat transfer between the partition walls and the outer peripheral wall and heat exchange between the outer peripheral wall and the second fluid, heat exchange can eventually be performed between the first fluid and the second fluid.

[0019] In particular, in a heat exchanger element of the present invention, since the first fluid is divided into a plurality of cells to promote the heat exchange between the first fluid and the partition walls in each cell, the temperature efficiency between the first fluid and the heat exchanger element is improved, and consequently temperature efficiency between the first fluid and the second fluid is improved.

[0020] In a heat exchanger element of the present invention, since the outer peripheral wall and partition walls are made of ceramic containing SiC as the main component, they have excellent corrosion resistance and high thermal conductivity. In such an outer peripheral wall and partition walls having high thermal conductivity, a temperature difference among portions is hardly caused. That is, in each of the outer peripheral wall and partition walls, the temperature difference between the portion having the highest temperature and the portion having the lowest temperature can be reduced. Therefore, in a heat exchanger element of the present invention, in the outer peripheral wall and the partition walls, generation of a large difference in contraction and expansion among portions can be inhibited. That is, in a heat exchanger element of the present invention, since the outer peripheral wall and the partition walls are made of ceramic containing SiC as the main component, generation of serious thermal stress in the outer peripheral wall and partition walls can be inhibited. As a result, in a heat exchanger element of the present invention, generation of a crack or breakage due to the thermal stress in the outer peripheral wall and the partition walls is inhibited.

[0021] The ceramic containing SiC as the main component in the present specification means ceramic containing 50 mass% or more of SiC. For example, partition walls made of ceramic containing SiC as the main component means partition walls containing 50 mass% or more of SiC.

[0022] Furthermore, in a heat exchanger element of the present invention, the thickness T of the outer peripheral wall, the equivalent circle diameter D calculated from the area of the portion inside the outer peripheral wall in a cross section perpendicular to an axial direction of the outer peripheral wall, and thickness t of the partition walls satisfy the following formulae (1) to (3):

$$\text{Formula (1): } 0.3 \text{ mm} \leq T \leq 4.0 \text{ mm}$$

$$\text{Formula (2): } 15 \text{ mm} \leq D \leq 120 \text{ mm}$$

$$\text{Formula (3): } 0.04 \times T \leq t \leq 0.6 \text{ mm.}$$

[0023] In a heat exchanger element of the present invention, since the thickness T of the outer peripheral wall satisfies $0.3 \text{ mm} \leq T \leq 4.0 \text{ mm}$, the rigidity of the outer peripheral wall is enhanced. By thus enhancing the rigidity of the outer peripheral wall, breakage of the outer peripheral wall is hardly caused in a heat exchanger element of the present invention. Consequently, a defect of mixing of the first fluid flowing through the portion inside the outer peripheral wall and the second fluid flowing through the portion outside the outer peripheral wall is hardly caused.

[0024] In addition, in a heat exchanger element of the present invention, since the aforementioned relations of the formulae (1) to (3) are satisfied, even if a crack or breakage is caused due to thermal stress in the partition walls, the crack or breakage can be inhibited from being extended to the degree of seriously lowering the temperature efficiency. Furthermore, when the aforementioned relations of the formulae (1) to (3) are satisfied, there can be inhibited a pressure drop caused when the first fluid flows through the portion inside the outer peripheral wall (specifically, inside the cells).

[0025] In a heat exchanger element of the present invention, it is preferable that the thickness T of the outer peripheral wall, the equivalent circle diameter D calculated from the area of the portion inside the outer peripheral wall in a cross section perpendicular to an axial direction of the outer peripheral wall, and thickness t of the partition walls satisfy the following formulae (4) to (6):

$$\text{Formula (4): } 0.5 \text{ mm} \leq T \leq 4.0 \text{ mm}$$

$$\text{Formula (5): } 30 \text{ mm} \leq D \leq 60 \text{ mm}$$

$$\text{Formula (6): } 0.04 \times T \leq t \leq 0.6 \text{ mm}$$

[0026] In a heat exchanger element of the present invention, when the aforementioned relations of the formulae (4) to (6) are satisfied, the rigidity of the outer peripheral wall is enhanced, and therefore a crack or breakage is hardly caused in the outer peripheral wall. In addition, also in the partition walls, a crack or breakage due to thermal stress is hardly caused. Further, in a heat exchanger element of the present invention, in the case that the outer peripheral wall has a cylindrical shape and that the relations of the aforementioned formulae (4) to (6) are satisfied, the effect of inhibiting generation of a crack or breakage in the outer peripheral wall and the effect of inhibiting generation of a crack or breakage in the partition walls can more securely be exhibited, which is preferable.

[0027] In a heat exchanger element of the present invention, it is preferable that a cross sectional shape of the cells is a polygon constituted of obtuse angles. In the case of such a polygonal cross-sectional shape of the cells, the difference in the rigidity of the partition walls among portions inside the outer peripheral wall is small. As a result, the difference in the magnitude of the thermal stress caused in the partition walls among portions inside the outer peripheral wall is small. When the variance of the thermal stress caused in the partition walls becomes small, the maximum generated stress in the partition walls inside the outer peripheral wall becomes small, and, as a result, generation of a crack or breakage in the partition walls can be inhibited more securely.

[0028] In a heat exchanger element of the present invention, it is preferable that at least one of the outer peripheral wall and partition walls is dense, and it is more preferable that both the outer peripheral wall and the partition walls are dense. When the outer peripheral wall is dense, the outer peripheral wall has high coefficient of thermal conductivity, and, as a result, the temperature efficiency of the heat exchanger element can be enhanced. In the same manner, when the partition walls are dense, the partition walls have high coefficient of thermal conductivity, and, as a result, the temperature efficiency of the heat exchanger element can be enhanced. Therefore, in a heat exchanger element of the present invention, in the case that both the outer peripheral wall and the partition walls are dense, it is possible to enhance the temperature efficiency more securely.

[0029] The term dense in the present specification means that the porosity is 10% or less. In a heat exchanger element of the present invention, in the case that the partition walls or the outer peripheral wall are/is dense, the porosity is preferably 5% or less. Incidentally, porosity used here means the porosity measured by the mercury porosimetry. For example, in the case that the outer peripheral wall or partition walls is/are made of porous ceramic (having a porosity of 30% or more) containing SiC as the main component, the coefficient of thermal conductivity is about 20 W/m·K. In contrast, in the case that the outer peripheral wall or partition walls is/are made of dense ceramic (having a porosity of 10% or less) containing SiC as the main component, the coefficient of thermal conductivity can be raised up to about 150 W/m·K.

[0030] It is preferable that a heat exchanger element of the present invention has a covering member for covering the outer peripheral wall. The covering member is provided so as to separate the first fluid from the second fluid. This enables to inhibit mixture of the first fluid and the second fluid even if breakage is generated in the outer peripheral wall. In addition, the covering member is provided so that heat exchange can be performed between the first fluid and the second fluid.

[0031] In the heat exchanger element of the present invention, the first fluid can be separated from the second fluid by a simple structure of the inside and the outside of a cylinder. Since the heat exchanger element can have a simple structure of a cylindrical shape, the heat exchanger can be manufactured by a simple assembly operation. For example, tubes are connected to both the ends of a heat exchanger element of the present invention to form a passage for the first fluid, and then the heat exchanger element is covered with a casing to assemble a heat exchanger easily (A concrete example of assembly of a heat exchanger is described later).

[0032] Hereinbelow, the content of a heat exchanger element of the present invention will be described in detail while showing concrete embodiments with referring to drawings.

[0033] Fig. 1 is a perspective view of one embodiment of a heat exchanger element of the present invention. As shown in the drawing, the heat exchanger element 1 of the present embodiment has a cylindrical outer peripheral wall 3. The outer peripheral wall 3 is open at both the end portions 9a and 9b. Therefore, the first fluid can be passed through the portion inside the outer peripheral wall 3 while employing one of the end portions 9a and 9b as the inlet and the other as the outlet.

[0034] In addition, in the present embodiment, the portion inside the outer peripheral wall 3 is partitioned to have a square lattice shape by the partition walls 7. This forms a plurality of cells 5 in the portion inside the outer peripheral wall 3. Therefore, the heat exchanger element of the present embodiment has a so-called honeycomb structure 20. Incidentally, though the external shape of the honeycomb structure 20 is cylindrical (circular columnar) in the present embodiment, the external shape of the honeycomb structure 20 is not limited to the cylindrical shape. For example, as modified examples of the present embodiment, an external cross-sectional shape of the honeycomb structure 20 may be an oval,

a quadrangle, or other polygons when the honeycomb structure 20 is viewed from a cross section perpendicular to the axial direction.

[0035] Furthermore, in the present embodiment, the partition walls 7 passes straight through the inside of the outer peripheral wall 3, and both the ends of each partition wall 7 are brought into contact with the outer peripheral wall 3. Since the partition walls 7 are thus in contact with the outer peripheral wall 3, heat transfer becomes possible between the partition walls 7 and the outer peripheral wall 3.

[0036] In addition, in the heat exchanger element 1 of the present embodiment, the outer peripheral wall 3 and the partition walls 7 are formed of ceramic containing SiC as the main component.

[0037] In addition, the outer peripheral wall 3 and the partition walls 7 can be formed of ceramic containing SiC impregnated with metal Si as the main component. In this case, the more the amount of metal Si is increased, the more the coefficient of thermal conductivity of the outer peripheral wall 3 and the partition walls 7 can be raised. For example, regarding ceramic containing SiC impregnated with metal Si as the main component, by impregnating 100 parts by mass of ceramic containing SiC before the metal Si impregnation as the main component with 30 parts by mass or more of metal Si, the coefficient of thermal conductivity can be made 100 W/m·K or more.

[0038] Specifically, as the material for the outer peripheral wall 3 and the partition walls 7, there can be employed Si-impregnated SiC, (Si+Al)-impregnated SiC, metal composite SiC, recrystallized SiC, Si_3N_4 , SiC, and the like. However, in the case that the outer peripheral wall 3 and the partition walls 7 made of a material listed above are porous (a porosity of 30% or more), it may be impossible to obtain a high coefficient of thermal conductivity. Therefore, in the case of employing Si-impregnated SiC, (Si+Al)-impregnated SiC, metal composite SiC, recrystallized SiC, Si_3N_4 , SiC, or the like as the material for the outer peripheral wall 3 and the partition walls 7, it is preferable to make the outer peripheral wall 3 and the partition walls 7 dense (a porosity of 10% or less) in order to obtain a high heat exchange effectiveness.

[0039] In order to make them dense, it is preferable to employ Si-impregnated SiC or (Si+Al)-impregnated SiC as the material for the outer peripheral wall 3 and the partition walls 7. The outer peripheral wall 3 and the partition walls 7 employing Si-impregnated SiC is densely formed with a high coefficient of thermal conductivity and thermal resistance to show sufficient strength. Though the coefficient of thermal conductivity is about 20 W/m·K in the case of porous (a porosity of 30% or more) SiC (silicon carbide), the coefficient of thermal conductivity in the case of dense (a porosity of 10% or less) Si-impregnated SiC is improved to about 150 W/m·K.

[0040] In addition, in the case of forming the outer peripheral wall 3 and the partition walls 7 from SiC-impregnated SiC, (Si+Al)-impregnating SiC, metal composite SiC, recrystallized SiC, Si_3N_4 , SiC, or the like, the outer peripheral walls 3 and the partition walls 7 can be excellent in thermal resistance, thermal shock resistance, oxidation resistance, corrosion resistance to acid and alkali, and, as a result, the heat exchanger element 1 can be made to be durable against long-period use.

[0041] Here, in the case that the outer peripheral wall 3 and the partition walls 7 contain Si-impregnated SiC or (Si+Al)-impregnated SiC as the main component, the ratio of Si content to the sum of Si content and SiC content $[\text{Si content} / (\text{Si content} + \text{SiC content})]$ is preferably 0.05 to 0.5, more preferably 0.1 to 0.4. When the ratio of Si content to the sum of Si content and SiC content is 0.05 or more, the bonding of SiC particles to each other by means of a Si phase becomes sufficient, thereby increasing the strength of the outer peripheral wall 3 and the partition walls 7. In addition, a sufficient coefficient of thermal conductivity can be obtained. When the ratio of Si content to the sum of Si content and SiC content is 0.5 or less, the amount of the Si phase does not become too excessive, and, as a result, upon forming the outer peripheral wall 3 and the partition walls 7 through firing and the like, an unfavorable phenomenon such as deformation is hardly caused.

[0042] Fig. 2 is a front view of an end portion 9a of the heat exchanger element 1 of the present embodiment. This front view shows the thickness T of the outer peripheral wall 3, the equivalent circle diameter D calculated from the area of the portion inside the outer peripheral wall 3 in a cross section perpendicular to an axial direction of the outer peripheral wall 3, and thickness t of the partition walls 3 in the heat exchanger element 1 of the present embodiment.

[0043] In the present embodiment, the outer peripheral wall 3 has a cylindrical shape having a uniform thickness. In addition, in the case of viewing the heat exchanger element 1 of the present embodiment from a cross section perpendicular to the axial direction, the cross section inside the outer peripheral wall 3 is circle. Therefore, the size of the aforementioned equivalent circle diameter D is the same as the size of the internal diameter of the outer peripheral wall 3.

[0044] In the case that the shape of the outer peripheral wall is other than the cylindrical shape, the area of the region surrounded by the surface inside the outer peripheral wall in a cross section perpendicular to the axial direction of the outer peripheral wall is obtained, and the diameter of the circle having the same area as the aforementioned area is calculated to determine the diameter as the equivalent circle diameter D.

[0045] Next, one concrete example of a heat exchanger having the heat exchanger element 1 of the present embodiment will be shown. With referring to drawings of the heat exchanger, the mode of heat exchange using the heat exchanger element 1 of the present embodiment will be described.

[0046] Fig. 3 shows a schematic view of a heat exchanger 21 having the heat exchanger element 1 shown in Fig. 1. As shown in the figure, in the heat exchanger 21 of the present embodiment, the aforementioned heat exchanger element

1 is arranged in a casing 11. The casing 11 used here is formed to have a rectangular parallelepiped box shape by walls 19. In the heat exchanger 21 of the present embodiment, a hole is made in each of a wall 19 of one face of the casing 11 and a wall 19 of the opposite side, and the end portion 9a and the end portion 9b of the heat exchanger element 1 are engaged with these holes. This allows the heat exchanger element 1 to pass through the inside of the casing 11. Furthermore, in the heat exchanger 21 of the present embodiment, the end portion 9a and the end portion 9b of the heat exchanger element 1 are connected to the tube 23a and tube 23b, respectively, outside the walls 19. As a result, in the heat exchanger 21 of the present embodiment, by sending the first fluid into the tube 23a, it can successively be sent to the inside of the heat exchanger element 1 and further to the tube 23b.

[0047] Fig. 4 is a cross sectional view along A-A' of Fig. 3. As shown in the figure, when the first fluid flows inside the heat exchanger element 1 (inside the outer peripheral wall 3), the first fluid is divided into a plurality of cells 5.

[0048] Further, as shown in Fig. 3, the casing 11 is provided with the inlet 13 for allowing the second fluid to flow into the casing 11 and the outlet 15 for discharging the second fluid outside from the casing 11.

[0049] Fig. 5 is a cross sectional view along B-B' of Fig. 3. As shown in the figure, when the second fluid flows into the casing 11 from the inlet 13, it flows with coming into contact with the outer peripheral face 4 of the outer peripheral wall 3 of the heat exchanger element 1 and is finally discharged from the outlet 15.

[0050] Though the description is made with referring to a rectangular parallelepiped box type casing 11 here, any shape can be employed as well as the first fluid can be passed the heat exchanger element or the first fluid passage formed by connecting tubes to the heat exchanger element through the inside of the casing and the second fluid can be passed along the outer periphery of the heat exchanger element inside the casing.

[0051] For example, if the first fluid has high temperature while the second fluid has low temperature, the heat transfer is caused from the first fluid to the second fluid. In the process of the heat transfer, heat transfers from the first fluid to the partition walls 7 and the outer peripheral wall 3 in the first place, and then it transfers from the outer peripheral wall 3 to the second fluid. At this time, the heat transfer from the first fluid to the outer peripheral wall 3 is performed by the two modes described below.

[0052] Since the first fluid flowing through the cells 5 present on the outermost periphery side (e.g., cells 5a of Fig. 5) is in contact with the outer peripheral wall 3, the heat can directly be transferred to the outer peripheral wall 3.

[0053] The first fluid flowing through the other cells (e.g., cells 5b and cells 5c of Fig. 5) can transfer heat to the outer peripheral wall 3 by means of the partition walls 7. For example, in the case of the first fluid flowing through the cells 5a of Fig. 5, heat is transferred from the first fluid to the partition walls 7 forming the cells 5a in the first place, and then heat sequentially passes from the partition walls 7 of the cells 5a to the partition walls 7 forming the other cells 5 so that the heat can be transferred to the outer peripheral wall 3. Thus, even when the first fluid flows without coming into contact with the outer peripheral wall 3, heat can be transferred securely to the outer peripheral wall 3 by using heat conduction of the partition walls 7.

[0054] In the heat exchanger element 1 of the present embodiment, for example, in the case that a hole or a crack is caused in the partition wall 7 shown by the frame α of the broken like in Fig. 5 (partition wall 7 separating the cell 5b from cell 5c), only the first fluid flowing through the cell 5b and that flowing through the cell 5c are mixed together. Therefore, it does not develop into a fatal malfunction of impairing the function as a heat exchanger element. Therefore, in the heat exchanger element 1 of the present embodiment, it is easy to suitably apply formation enabling to realize a higher temperature efficiency, such as thinning the partition walls 7 or forming partition walls 7 having a twisted shape as modified examples.

[0055] Further, in the heat exchanger element 1 of the present embodiment, the partition walls 7 play a role of structurally reinforcing the outer peripheral wall 3 as a beam. Since the partition walls 7 thus play a role as a beam, the outer peripheral wall 3 hardly has a hole or a crack. Therefore, in the heat exchanger element 1 of the present embodiment, a fatal malfunction of allowing the first fluid and the second fluid to be mixed together is hardly caused.

[0056] Fig. 6 is a perspective view of a modified example of the present embodiment. The heat exchanger element 100 of the present modified example has a cylindrical metal tube 40 and a graphite sheet 45. In Fig. 6, a part of the metal tube 40 is cut off so that the graphite sheet 45 present inside the metal tube 40 is exposed, and furthermore a part of the exposed graphite sheet 45 is cut off so that the outer peripheral wall 3 present inside the graphite sheet 45 is exposed. As illustrated, in the present modified example, the honeycomb structure 20 is housed inside the metal tube 40 in the state that the outer peripheral wall 3 is covered with the graphite sheet 45.

[0057] By covering the periphery of the outer peripheral wall 3 with the tubular wall of the metal tube 40, even if breakage is caused in the outer peripheral wall 3 to have a leakage of the first fluid outside the outer peripheral wall 3, the leaked first fluid can be shielded by the tubular wall of the metal tube 40 to inhibit the mixture of the first fluid and the second fluid.

[0058] In particular, as the modified example shown in Fig. 6, by putting the graphite sheet 45 between the outer peripheral wall 3 of the honeycomb structure 20 and the metal tube 40, heat exchange between the outer peripheral wall 3 and the metal tube 40 can be improved. Since the outer peripheral wall 3 is of ceramic material, it may be difficult to make the surface completely flat and smooth. The surface of the outer peripheral wall 3 in such a case has unevenness.

If the outer peripheral wall 3 having such unevenness is put inside the metal tube 40 without having the graphite sheet 45 between them, a protrusion of the surface of the outer peripheral wall 3 and the metal tube 40 is just brought into contact with each other in a scattered fashion, and good heat transfer between the outer peripheral wall 3 and the metal tube 40 becomes difficult. When the graphite sheet 45 is put between the outer peripheral wall 3 and the metal tube 40, since the graphite sheet 45 is flexible, it becomes possible that the graphite sheet 45 is allowed to enter the depressions of the surface of the outer peripheral wall 3 for contact. Thus, the outer peripheral wall 3 and the metal tube 40 can be brought into contact with the graphite sheet 45 in a wide range, and, as a result, good thermal conduction can be performed through the outer peripheral wall 3, the graphite sheet 45, and metal tube 40.

[0059] Fig. 7 is a perspective view of another modified example of the present embodiment. As illustrated, the heat exchanger element 150 of the present modified example has a quadrangular prism-shaped outer peripheral wall 3 having a hollow in the portion inside it. The portion inside the outer peripheral wall 3 is partitioned into a square lattice shape by the partition walls 7 to form a plurality of cells 5 in the portion inside the outer peripheral wall 3.

[0060] When the heat exchanger element 150 of the present modified example is viewed from a cross section perpendicular to the axial direction, the cross-sectional shape of the portion inside the outer peripheral wall 3 is a square having a side length of L (mm). Therefore, in this modified example, the equivalent circle diameter D calculated from the area of the portion inside the outer peripheral wall 3 in a cross section perpendicular to the axial direction of the outer peripheral wall 3 is $2L/\pi^{1/2}$ (mm).

[0061] Fig. 8 is an enlarged view of one end portion of a heat exchanger element of an embodiment of the present invention. As illustrated, in the heat exchanger element 210 of the present embodiment, the cross-sectional shape of the cells 5 is a regular hexagon (polygon having an interior angle of 120 degree in the cross-sectional shape of a cell). Since the cross-sectional shape of the cell is a polygon having obtuse interior angles, thermal stress caused in the partition walls 7 is relaxed. As a result, generation of a crack or breakage in the partition walls 7 can be inhibited.

[0062] Fig. 9 is an enlarged view of one end portion of a heat exchanger element of one embodiment of the present invention. As illustrated, in the heat exchanger element 220 of the present embodiment, there is a notch 31 in a part of the partition walls 7. Since a partition wall 7 has a notch 31, the thermal stress caused in the partition wall 7 can be relaxed, and, as a result, generation of a crack or breakage in the partition walls 7 can be inhibited. In particular, by forming a notch 31 in the vicinity of a position where the largest thermal stress is generated among the partition walls 7, thermal stress generated in the partition walls 7 can be relaxed more effectively. As a result, generation of a crack or breakage in the partition walls 7 can be inhibited furthermore securely.

[0063] Fig. 10 is a cross section of a heat exchanger element of an embodiment of the present invention. As illustrated, in the heat exchanger element 230 of the present embodiment, the outer peripheral wall 3 has a notch 33. By forming the notch 33 in the outer peripheral wall 3, thermal stress caused in the outer peripheral wall 3 can be relaxed, and, as a result, generation of a crack and breakage in the outer peripheral wall 3 can be inhibited. In particular, as the notch 33 shown in Fig. 10, forming a notch 33 in a position where a plurality of partition walls 7 intersect each other in the outer peripheral wall 3 is preferable because also the thermal stress caused in the plurality of partition walls 7 can be relaxed.

[0064] Fig. 11 is a cross-sectional view of a heat exchanger element of one embodiment of the present invention. As illustrated, in the heat exchanger element 240 of the present embodiment, the partition walls 7 in the central portion inside the outer peripheral wall 3 are thin, and the partition walls 7 in the outer peripheral portion are thick. In the case that the partition walls 7 in the central portion inside the outer peripheral wall 3 is thinner than the partition walls 7 in the outer peripheral portion, the thermal stress generated in the partition walls 7 in the central portion can be reduced. As a result, generation of a crack or breakage in the partition walls 7 in the central portion can be inhibited. On the other hand, since the partition walls 7 in the outer peripheral portion are thicker than those in the central portion, they are at risk of generating large thermal stress. However, the partition walls 7 in the outer peripheral portion are closer to the joint portion of the partition walls 7 and the outer peripheral wall 3, strength is increased by the outer peripheral wall 3. Therefore, even in the partition walls 7 in the outer peripheral portion, generation of a crack and breakage is inhibited.

Examples

[0065] Hereinbelow, the present invention will be described in more detail on the basis of Examples. However, the present invention is not limited to these Examples.

(1) Heat exchanging member

(Manufacturing of kneaded clay)

[0066] In the first place, 70 mass% of a SiC powder having an average particle diameter of 45 μm , 10 mass% of SiC powder having an average particle diameter of 35 μm , and 20 mass% of a SiC powder having an average particle diameter of 5 μm were mixed together to prepare a mixture of SiC powders. To 100 parts by mass of the mixture of SiC

powders were added 4 parts by mass of a binder, and water, and they were kneaded by the use of a kneader to obtain a kneaded material. This kneaded material was put into a vacuum kneader to manufacture kneaded clay formed in a circular columnar shape.

5 (Extrusion forming)

10 **[0067]** Next, the kneaded clay was extruded to form a honeycomb formed body. In the extrusion, by selecting a die and a jig having an appropriate form, the shape and thickness of the outer peripheral wall, thickness of the partition walls, cell shape, cell density, and the like were made to be desirable. The die employed was made of superhard alloy which hardly abrade away. Regarding the honeycomb formed body, the outer peripheral wall was made to have a cylindrical shape or a hollow quadrangular prism shape, and the portion inside the outer peripheral wall was formed to have a structure partitioned in a square lattice shape by partition walls. These partition walls were formed in parallel with one another at regular intervals in each of the directions perpendicular to each other so as to pass straight through the portion inside the outer peripheral wall. This made the square cross-sectional shape of the cells in portions except for the outermost peripheral portion inside the outer peripheral wall.

(Drying)

20 **[0068]** Next, the honeycomb formed body obtained by the extrusion was dried. In the first place, the honeycomb formed body was dried in a microwave heating method and then dried in an external heating method. By such two-step drying, moisture corresponding to 97% or more of the entire moisture contained in the honeycomb formed body before drying was removed from the honeycomb formed body.

(Degreasing, impregnation of Si metal, and firing)

25 **[0069]** Next, the honeycomb formed body was subjected to degreasing at 500°C for five hours in a nitrogen atmosphere. Further, a block of metal Si was put on the honeycomb structure obtained by such degreasing, and they were fired at 1450°C for four hours in an inert gas in a vacuum or under reduced pressure. During the firing, the metal Si block put on the honeycomb structure was melted to impregnate the outer peripheral wall and the partition walls with metal Si. In the case of making the coefficient of thermal conductivity of the outer peripheral wall and the partition walls 100 W/m·K, there was used 70 parts by mass of a metal Si block with respect to 100 parts by mass of the honeycomb structure. In addition, in the case of making the coefficient of thermal conductivity of the outer peripheral wall and the partition walls 150 W/m·K, there was used 80 parts by mass of a metal Si block with respect to 100 parts by mass of the honeycomb structure. Through such firing, a heat exchanger element was obtained. Incidentally, more detail form and the like of the heat exchanger element will be described below when each Example and each Comparative Example are individually described.

(Examples 1 to 8, Comparative Examples 1 and 2)

40 **[0070]** There were manufactured heat exchanger elements each having a cylindrical outer peripheral wall and having basically the same structure as that shown in Fig. 1. Specifically, there were manufactured heat exchanger elements each having an entire length of 100 mm, an outer peripheral wall thickness T of 1.0 mm, a partition wall thickness t of 0.5 mm, a cell density of 24 cells/cm², a thermal conductivity coefficient of 150 W/m·K of the outer peripheral wall and the partition walls, and an equivalent circle diameter D (same as the inner diameter of the outer peripheral wall here) calculated from the area of the portion inside the outer peripheral wall as shown in Table 1.

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[0071]

[Table 1]

	T (mm)	D (mm)	0.04×T (mm)	t (mm)	Temperature efficiency (%)	Pressure drop (kPa)	Number of breakage	Isostatic strength (MPa)	Isostatic strength Evaluation	Comprehensive evaluation
Comp. Ex. 1	1.0	10	0.04	0.5	85	143.39	0	>20	○	×
Example 1	1.0	15	0.04	0.5	85	59.5	0	>20	○	○
Example 2	1.0	20	0.04	0.5	85	33.27	0	>20	○	○
Example 3	1.0	30	0.04	0.5	85	9.38	0	>20	○	○
Example 4	1.0	40	0.04	0.5	85	3.80	0	>20	○	○
Example 5	1.0	50	0.04	0.5	80	1.94	0	>20	○	○
Example 6	1.0	60	0.04	0.5	80	1.16	0	>20	○	○
Example 7	1.0	80	0.04	0.5	70	0.54	3	>20	○	○
Example 8	1.0	120	0.04	0.5	50	0.25	4	>20	○	○
Comp. Ex. 2	1.0	130	0.04	0.5	35	0.23	8	1.0	×	×

(Examples 9 to 22, Comparative Examples 3 to 10)

[0072] There were manufactured heat exchanger elements each having a cylindrical outer peripheral wall and having basically the same structure as that shown in Fig. 1. Specifically, there were manufactured heat exchanger elements each having an entire length of 100 mm, an equivalent circle diameter D (same as the inner diameter of the outer peripheral wall here) of 45 mm calculated from the area of the portion inside the outer peripheral wall, a cell density of 24 cells/cm², a thermal conductivity coefficient of 150 W/m·K of the outer peripheral wall and the partition walls, and an outer peripheral wall thickness T and a partition wall thickness t as shown in Table 2.

[0073]

[Table 2]

	T (mm)	D (mm)	0.04×T (mm)	t (mm)	Temperature efficiency (%)	Pressure drop (kPa)	Number of breakage	Isostatic strength		Comprehensive evaluation
								(MPa)	Evaluation	
Comp. Ex. 3	0.2	45	0.008	0.1	30	1.88	5	0.3	×	×
Comp. Ex. 4	0.2	45	0.008	0.4	40	3.31	5	1.0	×	×
Comp. Ex. 5	0.2	45	0.008	0.6	40	7.71	8	1.0	×	×
Example 9	0.3	45	0.012	0.1	70	1.88	2	15	○	○
Example 10	0.3	45	0.012	0.4	85	3.31	1	>20	○	○
Example 11	0.3	45	0.012	0.6	85	7.71	3	>20	○	○
Example 12	0.5	45	0.02	0.1	70	1.88	○	15	○	○
Example 13	0.5	45	0.02	0.4	85	3.31	0	>20	○	○
Example 14	0.5	45	0.02	0.6	85	7.71	0	>20	○	○
Comp. Ex. 6	0.5	45	0.02	0.7	35	10.04	4	1.2	×	×
Example 15	1.0	45	0.04	0.1	70	1.88	0	15	○	○
Example 16	1.0	45	0.04	0.4	85	3.31	0	>20	○	○
Example 17	1.0	45	0.04	0.6	85	7.71	0	>20	○	○
Example 18	2.0	45	0.08	0.1	70	1.88	0	15	○	○
Example 19	2.0	45	0.08	0.4	85	3.31	0	>20	○	○
Example 20	2.0	45	0.08	0.6	85	7.71	0	>20	○	○
Example 21	4.0	45	0.16	0.4	85	3.31	0	>20	○	○
Example 22	4.0	45	0.16	0.6	85	7.71	0	>20	○	○
Comp. Ex. 7	4.0	45	0.16	0.1	35	1.88	1	0.3	×	×
Comp. Ex. 8	5.0	45	0.2	0.1	35	1.88	3	0.3	×	×
Comp. Ex. 9	5.0	45	0.2	0.4	40	3.31	2	1.0	×	×
Comp. Ex. 10	5.0	45	0.2	0.6	40	7.71	3	1.0	×	×

(Examples 23 to 36, Comparative Examples 11 to 17)

[0074] There were manufactured heat exchanger elements each having a cylindrical outer peripheral wall and having basically the same structure as that shown in Fig. 1. Specifically, there were manufactured heat exchanger elements each having an entire length of 100 mm, an equivalent circle diameter D (same as the inner diameter of the outer peripheral wall here) of 45 mm calculated from the area of the portion inside the outer peripheral wall, a cell density of 24 cells/cm², a thermal conductivity coefficient of 100 W/m·K of the outer peripheral wall and the partition walls, and an outer peripheral wall thickness T and a partition wall thickness t as shown in Table 3.

[0075]

[Table 3]

	T (mm)	D (mm)	0.04×T (mm)	t (mm)	Temperature efficiency (%)	Pressure drop (kPa)	Number of breakage	Isostatic strength		Comprehensive evaluation
								(MPa)	Evaluation	
Comp. Ex. 11	0.2	45	0.008	0.1	25	1.88	7	0.3	×	×
Comp. Ex. 12	0.2	45	0.008	0.4	35	3.31	8	1.0	×	×
Comp. Ex. 13	0.2	45	0.008	0.6	35	7.71	8	1.0	×	×
Example 23	0.3	45	0.012	0.1	70	1.88	6	15	○	○
Example 24	0.3	45	0.012	0.4	80	3.31	4	>20	○	○
Example 25	0.3	45	0.012	0.6	80	7.71	4	>20	○	○
Example 26	0.5	45	0.02	0.1	70	1.88	0	15	○	○
Example 27	0.5	45	0.02	0.4	80	3.31	0	>20	○	○
Example 28	0.5	45	0.02	0.6	80	7.71	0	>20	○	○
Example 29	1.0	45	0.04	0.1	70	1.88	0	15	○	○
Example 30	1.0	45	0.04	0.4	80	3.31	0	>20	○	○
Example 31	1.0	45	0.04	0.6	80	7.71	0	>20	○	○
Example 32	2.0	45	0.08	0.1	70	1.88	0	15	○	○
Example 33	2.0	45	0.08	0.4	80	3.31	0	>20	○	○
Example 34	2.0	45	0.08	0.6	80	7.71	0	>20	○	○
Comp. Ex. 14	4.0	45	0.16	0.1	30	1.88	2	0.3	×	×
Example 35	4.0	45	0.16	0.4	80	3.31	0	>20	○	○
Example 36	4.0	45	0.16	0.6	80	7.71	0	>20	○	○
Comp. Ex. 15	5.0	45	0.20	0.1	30	1.88	3	0.3	×	×
Comp. Ex. 16	5.0	45	0.20	0.4	35	3.31	5	1.0	×	×
Comp. Ex. 17	5.0	45	0.20	0.6	35	7.71	3	1.0	×	×

(Examples 37 to 44, Comparative Examples 18 and 19)

[0076] There were manufactured heat exchanger elements each having a quadrangular prism-shaped outer peripheral wall and having basically the same structure as that shown in Fig. 7. Specifically, there were manufactured heat exchanger elements each having an entire length of 100 mm, an outer peripheral wall thickness T of 1.0 mm, a partition wall thickness t of 0.5 mm, a cell density of 24 cells/cm², a thermal conductivity coefficient of 150 W/m·K of the outer peripheral wall and the partition walls, and an equivalent circle diameter D calculated from the area of the portion inside the outer peripheral wall as shown in Table 4. The cross section of the portion inside the outer peripheral wall in the case of viewing the thermal exchanging member from a cross section perpendicular to the axial direction was square, and the length of a side was as shown in Table 4.

[0077]

[Table 4]

	T (mm)	D (mm)	Length of a side of portion inside outer peripheral wall (mm)	$0.04 \times T$ (mm)	t (mm)	Temperature efficiency (%)	Pressure drop (kPa)	Number of breakage	Isostatic strength		Comprehensive evaluation
									(MPa)	Evaluation	
Comp. Ex. 18	1.0	9	8	0.04	0.5	85	145.5	0	>20	○	×
Example 37	1.0	13	11.5	0.04	0.5	85	61.5	0	>20	○	○
Example 38	1.0	18	16	0.04	0.5	85	35.3	0	>20	○	○
Example 39	1.0	27	24	0.04	0.5	85	10.4	0	>20	○	○
Example 40	1.0	35	31	0.04	0.5	85	4.80	0	>20	○	○
Example 41	1.0	44	39	0.04	0.5	80	2.14	0	>20	○	○
Example 42	1.0	53	47	0.04	0.5	80	1.36	0	>20	○	○
Example 43	1.0	71	63	0.04	0.5	70	0.74	3	>20	○	○
Example 44	1.0	106	94	0.04	0.5	50	0.35	4	>20	○	○
Comp. Ex. 19	1.0	130	115	0.04	0.5	35	0.25	8	1.0	×	×

(2) Heat exchanger

[0078] Each of the aforementioned heat exchanger elements of Examples and Comparative Examples was put in a casing to manufacture heat exchangers (heat exchangers having basically the same structure as shown in Fig. 3). There was used a casing having a shape where the gap between the outer peripheral wall of the heat exchanger element and wall surfaces of the casing was 1 mm in each portion. That is, each of the heat exchanger element having a cylindrical outer peripheral wall was put in a cylindrical casing (Examples 1 to 36, Comparative Examples 1 to 17). Each of the heat exchanger elements having a quadrangular prism-like outer peripheral wall was put in a rectangular parallelepiped box type casing (Examples 37 to 44, Comparative Examples 18 and 19). Incidentally, for each of Examples and Comparative examples, 10 heat exchangers were manufactured, and the 10 heat exchangers were subjected to the following heat exchange test and the like.

(3) Heat exchange test

[0079] In the aforementioned heat exchangers, nitrogen gas was used as the first fluid, and water was used as the second fluid to perform the heat exchange test. The temperature of the nitrogen gas was 500°C, the flow rate was 20 g/s, and the flow rate of water was 5 L/min. In addition, the heat exchange test was carried out after it was confirmed that the temperature of nitrogen gas at the outlet (temperature of nitrogen gas right after being discharged from the outlet side of the heat exchanger element) and the temperature of water at the outlet (temperature of water when the water was passing through the outlet of the casing) were stabilized.

[0080] There were measured the temperature of the first fluid just before flowing into the end portion on the inlet side of the heat exchange member as "inlet gas temperature" and the temperature of the first fluid right after being discharged from the end portion on the outlet side of the heat exchanger element as "outlet gas temperature". In addition, the temperature of water passing through the inlet of the casing was measured as "inlet water temperature". From these temperature values, the heat exchange efficiencies (%) were calculated from the following formula. The results are shown in Tables 1 to 4.

$$\text{Heat exchange efficiency (\%)} = (\text{inlet gas temperature} - \text{outlet gas temperature}) / (\text{inlet gas temperature} - \text{inlet water temperature}) \times 100$$

(4) Measurement of pressure drop

[0081] In the aforementioned heat exchange test, pressure gauges were disposed in a nitrogen gas passage located in front and at the back of the heat exchanger element. From the differential pressure obtained from the measured values of these pressure gauges, the pressure drop of the nitrogen gas flowing through the heat exchanger element (cells) was measured. Regarding each Example and each Comparative Example, the average value of the pressure drops measured in a total of 10 heat exchangers is shown in Tables 1 to 4.

(5) Inspection for breakage

[0082] Regarding each Example and each Comparative Example, after manufacturing a total of 10 heat exchangers and carrying out the heat exchange test as described above, the heat exchanger elements were taken out of each of the 10 heat exchangers, and presence/absence of breakage in the partition walls and the outer peripheral wall was observed. The number of the heat exchanger elements having breakage among the 10 heat exchanger elements is shown in Tables 1 to 4.

(6) Isostatic strength test

[0083] An urethane rubber sheet having a thickness of 0.5 mm was wrapped around the outer peripheral wall of the heat exchanger element. Further, an aluminum plate having a thickness of 20 mm was disposed on both the end portions of the heat exchanger element with a circular urethane rubber sheet put therebetween. The aluminum plate and the urethane rubber sheet had the same shape and the same size as those of the end portion of the heat exchanger element (e.g., in the case that the outer peripheral wall has a cylindrical shape, i.e., that the end portion has a circular shape, an aluminum circular plate was used). Further, a vinyl tape was wound around the outer periphery of the aluminum plate

to seal the gap between the outer periphery of the aluminum plate and the urethane rubber sheet. Thus, a test sample was obtained. Next, the test sample was put in a pressure container filled with water. Then, pressure of the water in the pressure container was raised to 20 MPa at a rate of 0.3 to 3.0 MPa/min., and the hydraulic pressure was measured when breakage was caused in the heat exchanger element. The hydraulic pressure at the time of generating breakage in the heat exchanger element is shown in Tables 1 to 4. Incidentally, when no breakage was caused even under a hydraulic pressure of 20 MPa, it was indicated as ">20" in Tables 1 to 4. In the case that the hydraulic pressure at the time of generating breakage in the heat exchanger element was above 1.0 Mpa, the isostatic strength was judged as "passed" (shown by "o" in Tables 1 to 4"). In the case that the hydraulic pressure at the time of generating breakage in the heat exchanger element was 1.0 MPa or less, the isostatic strength was judged as "failed" (shown by "×" in Tables 1 to 4").

(7) Comprehensive evaluation

[0084] When two conditions of "pressure drop of 70 kPa or less" and "isostatic strength of above 1.0 MPa" were satisfied, the comprehensive evaluation was judged as "passed" (shown by "○" in Tables 1 to 4"). In the case that at least one of the two conditions was not satisfied, the comprehensive evaluation was judged as "failed" (shown by "×" in Tables 1 to 4").

Industrial Applicability

[0085] The present invention can be used as a heat exchanger element fixed to a heat exchanger for use.

Description of Reference Numerals

[0086] 1: heat exchanger element, 3: outer peripheral wall, 4: outer peripheral face, 5, 5a to 5c: cell, 7: partition wall, 9, 9a, 9b: end portion, 11: casing, 13: inlet (of the second fluid), 15: outlet (of the second fluid), 17: passage (of the second fluid), 19: wall, 20: honeycomb structure, 21: heat exchanger, 23a, 23b: tube, 31: notch (in partition wall), 33: notch (in outer peripheral wall), 40: metal tube, 45: graphite sheet, 100, 150, 210, 220, 230, 240: heat exchanger element

Claims

1. A heat exchanger element comprising:

a cylindrical outer peripheral wall made of ceramic containing SiC as a main component, and partition walls which are made of ceramic containing SiC as a main component and separate and form a plurality of cells functioning as passages for a first fluid in a portion inside the outer peripheral wall; wherein the outer peripheral wall and the partition walls mediate heat exchange between the first fluid flowing through the portion inside the outer peripheral wall and the second fluid flowing through the portion outside the outer peripheral wall, and the thickness T of the outer peripheral wall, the equivalent circle diameter D calculated from the area of the portion inside the outer peripheral wall in a cross section perpendicular to an axial direction of the outer peripheral wall, and thickness t of the partition walls satisfy the following formulae (1) to (3):

$$\text{Formula (1): } 0.3 \text{ mm} \leq T \leq 4.0 \text{ mm}$$

$$\text{Formula (2): } 15 \text{ mm} \leq D \leq 120 \text{ mm}$$

$$\text{Formula (3): } 0.04 \times T \leq t \leq 0.6 \text{ mm}$$

2. The heat exchanger element according to Claim 1, wherein the thickness T of the outer peripheral wall, the equivalent circle diameter D calculated from the area of the portion inside the outer peripheral wall in a cross section perpendicular to an axial direction of the outer peripheral wall, and thickness t of the partition walls satisfy the following formulae (4) to (6):

Formula (4): $0.5 \text{ mm} \leq T \leq 4.0 \text{ mm}$

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Formula (5): $30 \text{ mm} \leq D \leq 60 \text{ mm}$

Formula (6): $0.04 \times T \leq t \leq 0.6 \text{ mm}$

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3. The heat exchanger element according to Claim 1 or 2, wherein a cross sectional shape of the cells is a polygon constituted of obtuse angles.

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4. The heat exchanger element according to any one of Claims 1 to 3, wherein at least one of the outer peripheral wall and the partition walls is dense.

5. The heat exchanger element according to any one of Claims 1 to 4, which has a covering member provided to separate the first fluid from the second fluid and covering the outer peripheral wall so as to be able to exchange heat between the first fluid and the second fluid.

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FIG.1

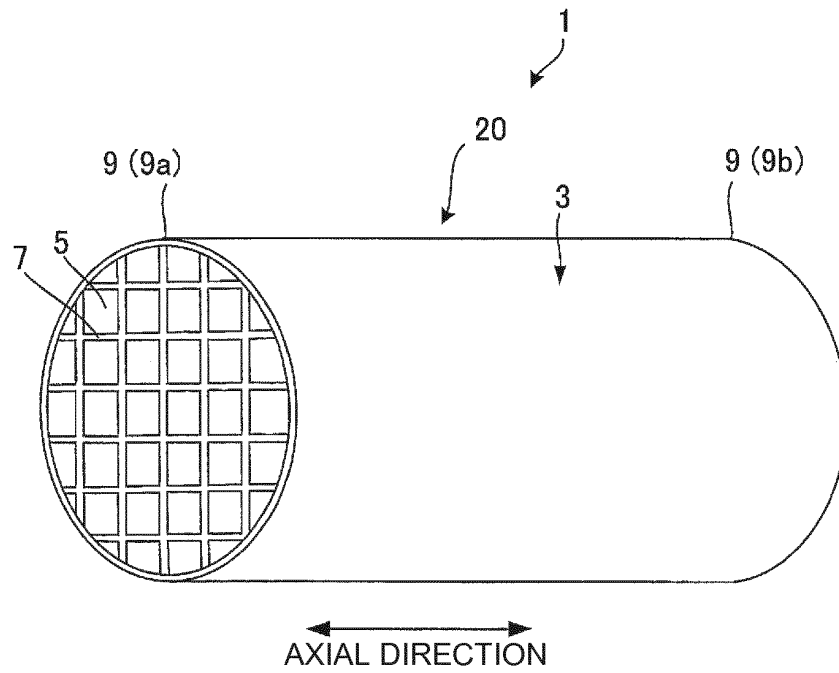


FIG.2

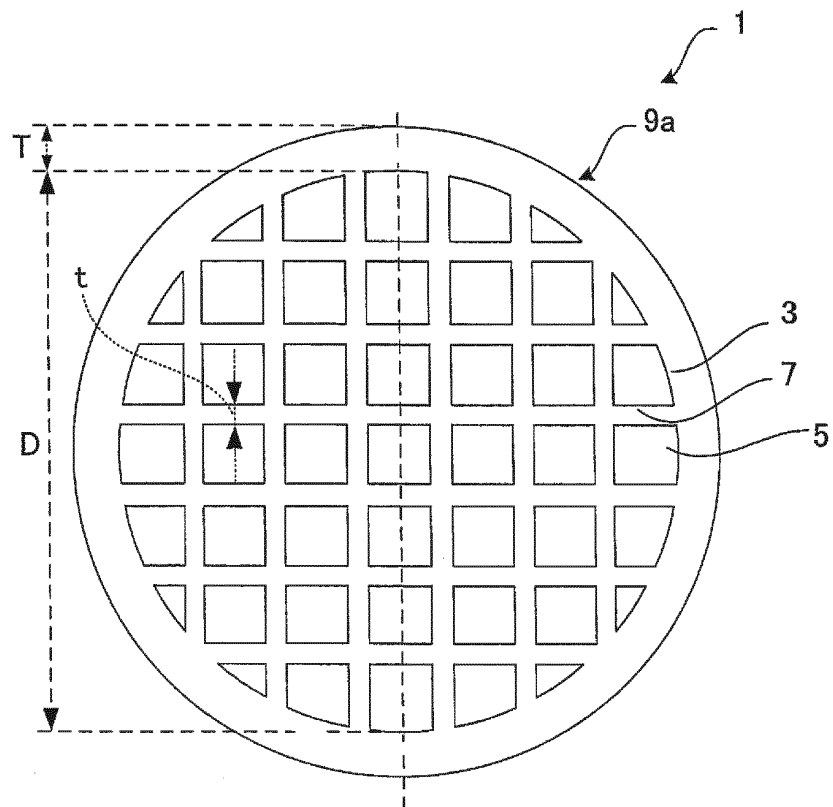


FIG.3

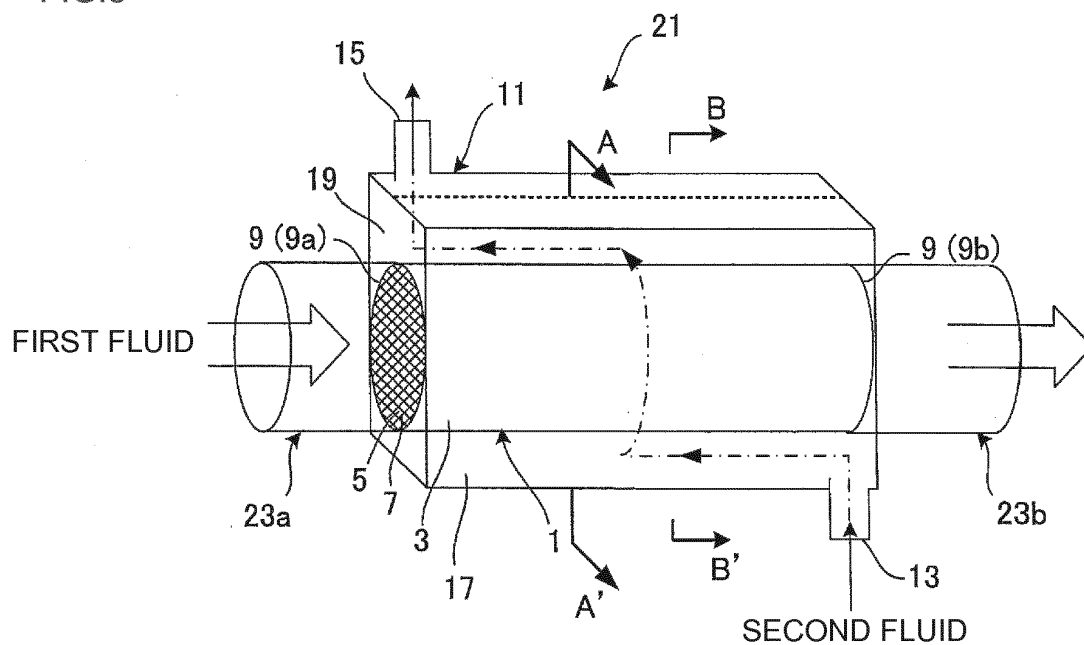


FIG.4

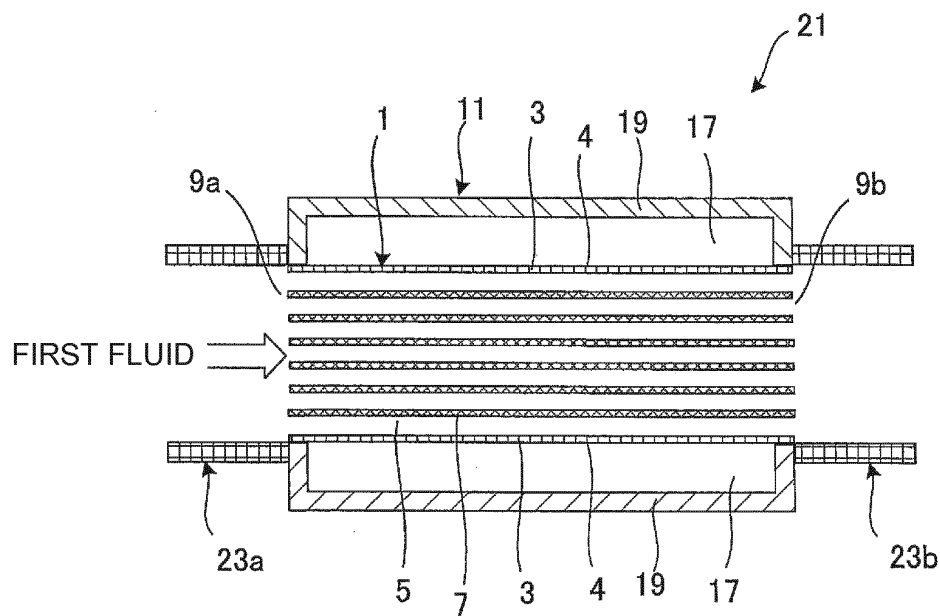


FIG.5

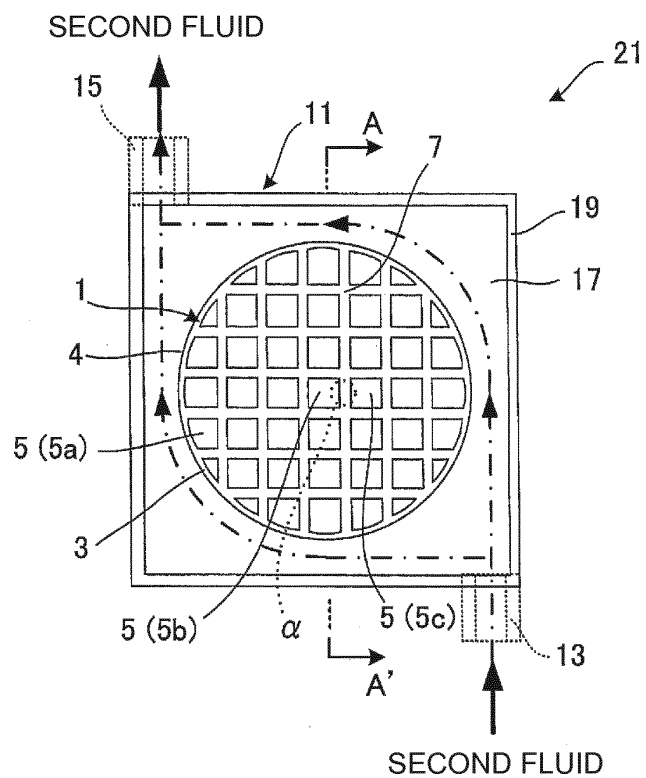


FIG.6

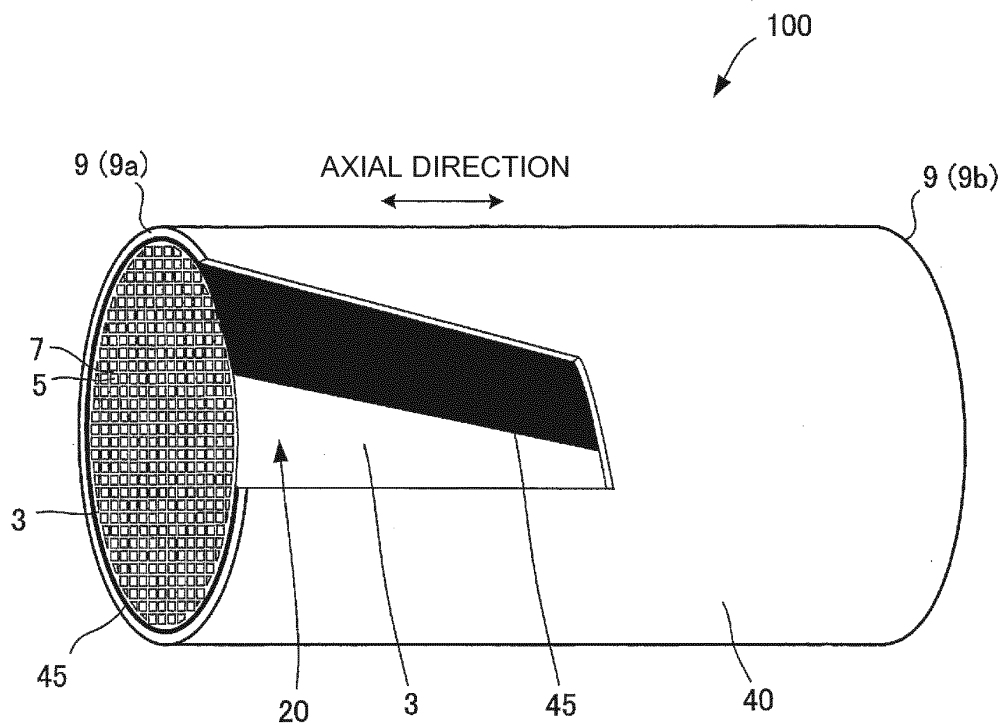


FIG.7

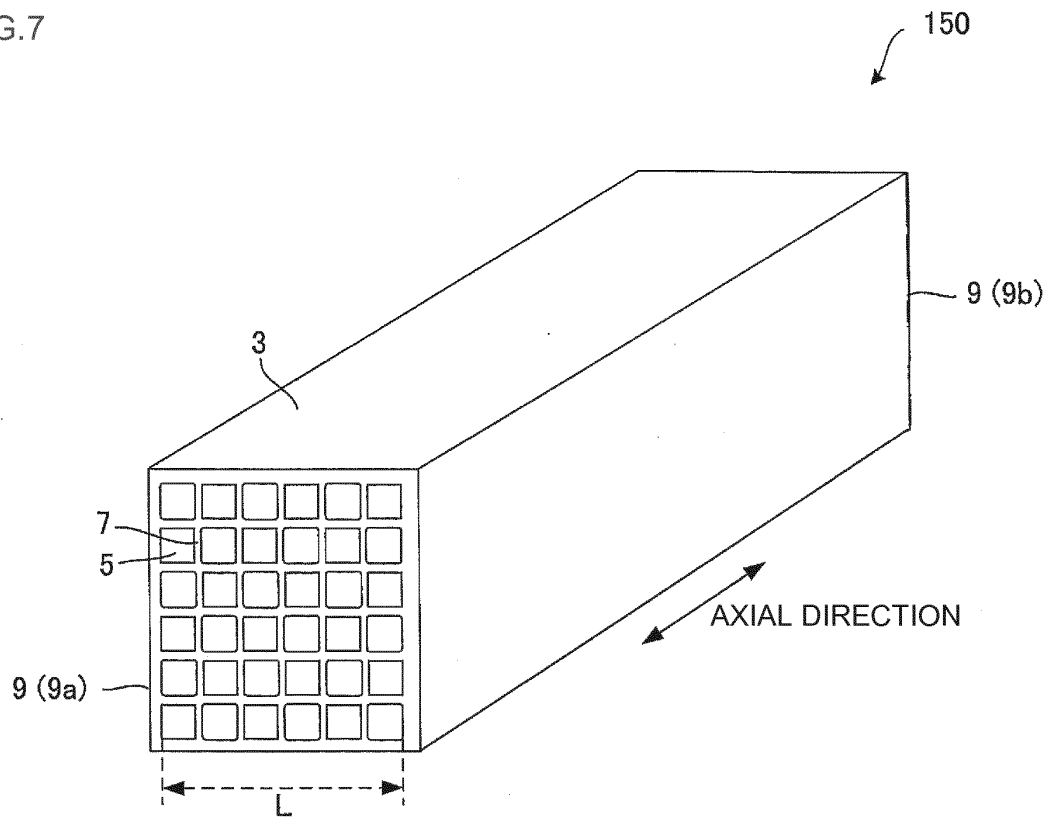


FIG.8

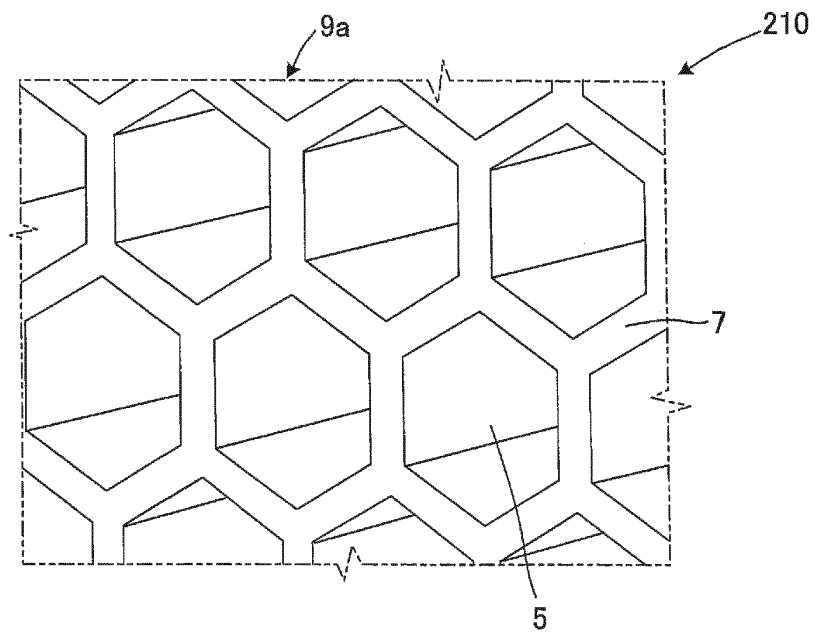


FIG.9

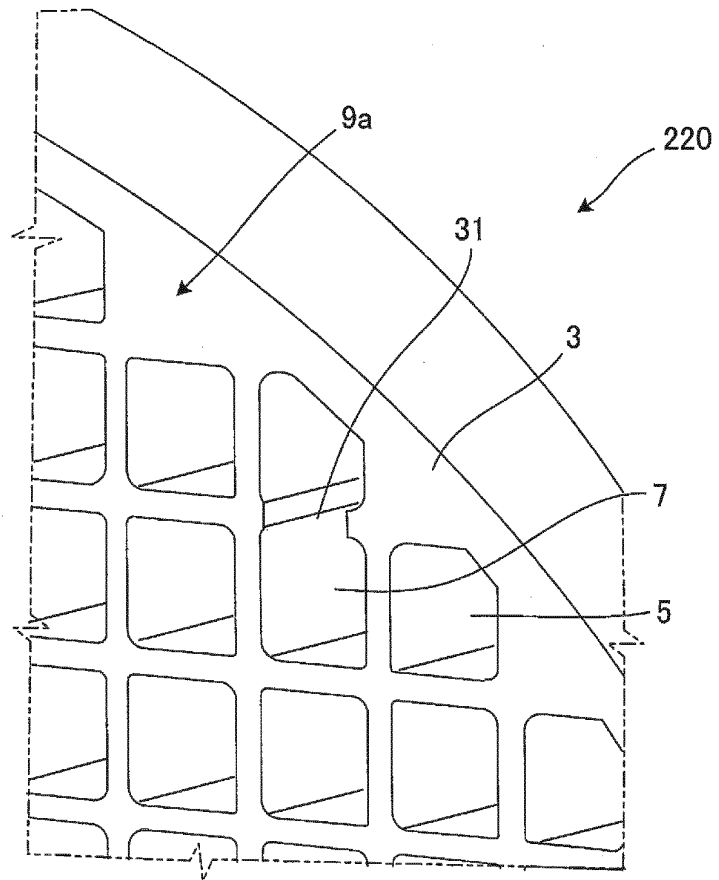


FIG.10

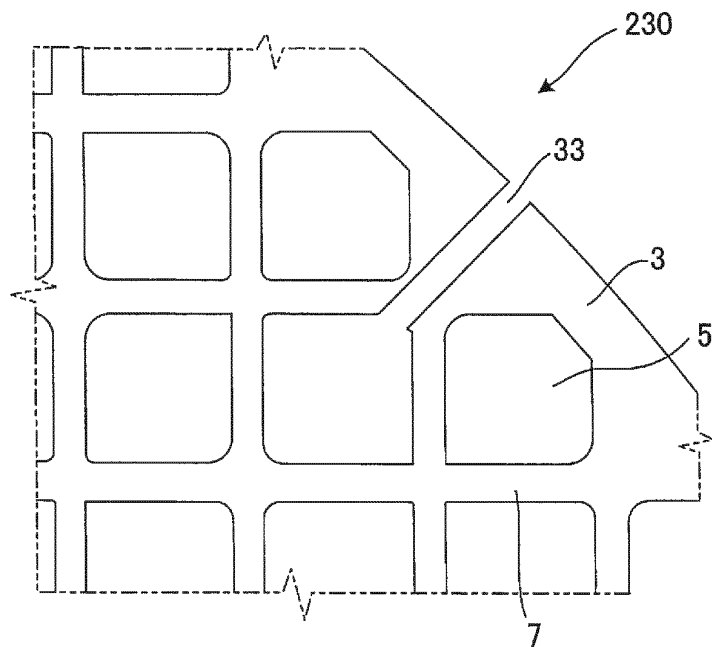
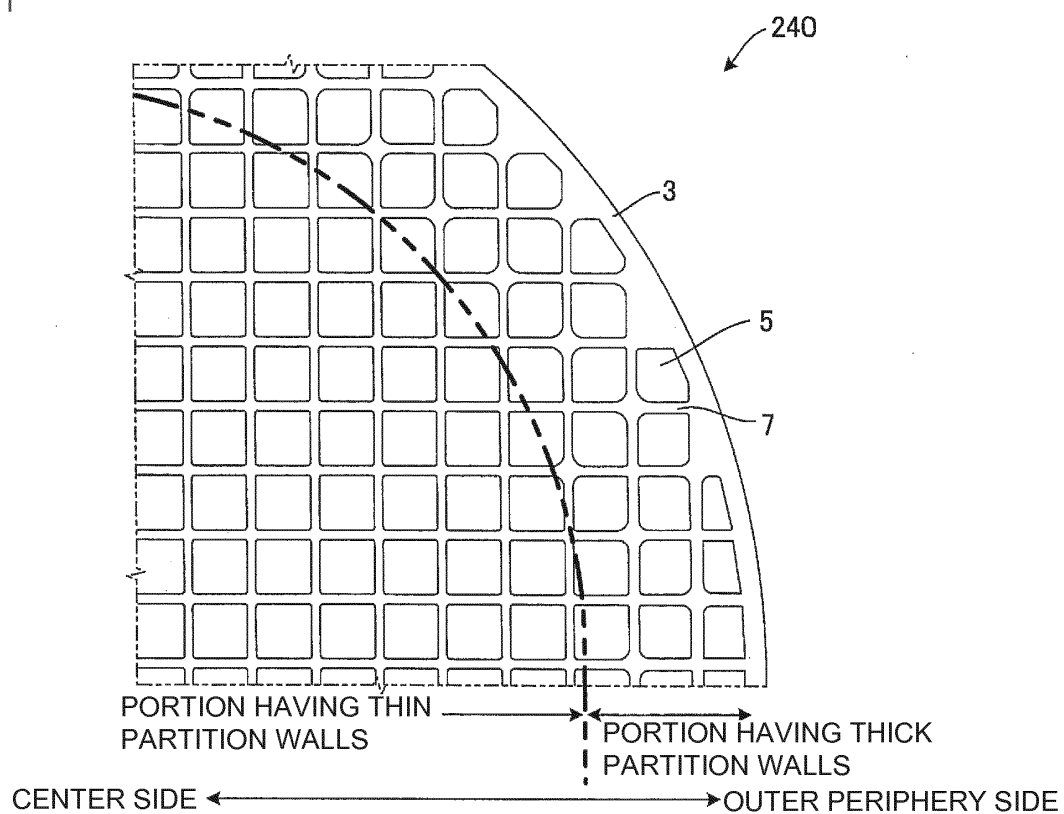


FIG.11



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/072454

A. CLASSIFICATION OF SUBJECT MATTER F28F21/04(2006.01) i, F28D7/10(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) F28F21/04, F28D7/10		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2011 Kokai Jitsuyo Shinan Koho 1971-2011 Toroku Jitsuyo Shinan Koho 1994-2011		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 62-9183 A (Kyocera Corp.), 17 January 1987 (17.01.1987), page 2, upper right column, line 17 to page 3, lower left column, line 9; fig. 1 to 3 (Family: none)	1-5
Y	WO 02/11884 A1 (NGK Insulators, Ltd.), 14 February 2002 (14.02.2002), page 4, line 15 to page 5, line 6 & US 6656564 B2 & EP 1360991 A1 & AU 7671301 A & CA 2386107 A & CN 1392803 A & ZA 200202642 A	1-5
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
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Date of the actual completion of the international search 16 December, 2011 (16.12.11)		Date of mailing of the international search report 27 December, 2011 (27.12.11)
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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