(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 837 861 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
26.09.2007 Bulletin 2007/39

(51) Int Cl.:
G10K 11/16 *(2006.01)*

(21) Application number: **07005918.3**

(22) Date of filing: **22.03.2007**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK YU

(30) Priority: **24.03.2006 JP 2006082534**

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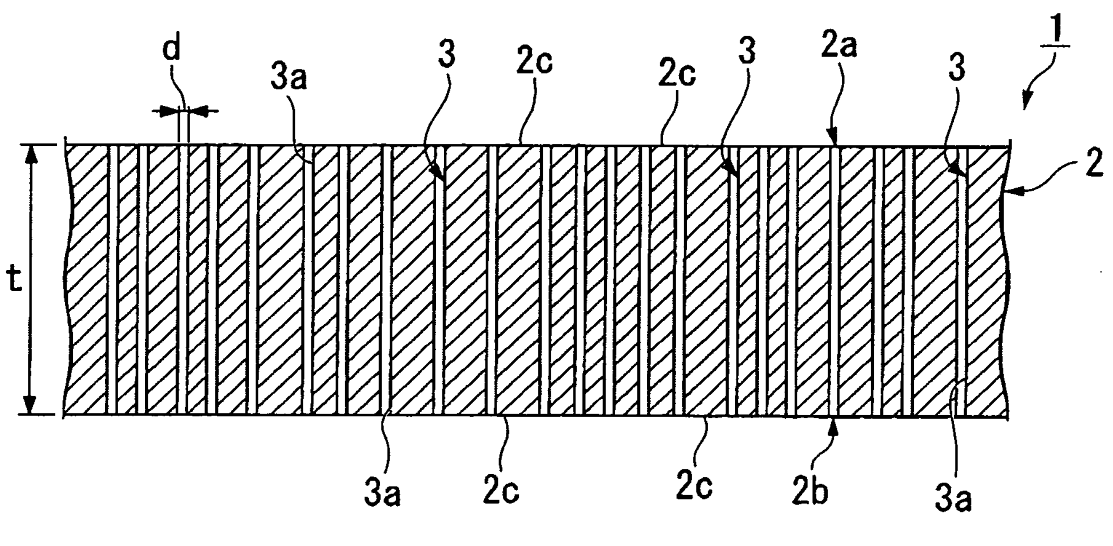
(54) **Sound-absorbing material, production method of the same, and sound-absorbing-panel**

(57) In order to provide a sound-absorbing material and a sound-absorbing panel which can be produce at a low-cost and have excellent beauty or appearance and excellent sound-absorbing characteristics, the sound-absorbing material is applied which is made from a metallic plate member (2), and multiple pierced apertures of 200μm or smaller diameter are arranged along a board thickness on the plate-shaped member (2).

FIG. 2



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a sound-absorbing material, a production method of the same and a sound-absorbing panel.

[0002] Priority is claimed on Japanese Patent Application No. 2006-82534, filed March 24, 2006, the content of which is incorporated herein by reference.

Description of the Related Art

[0003] As sound-absorbing materials of the prior art, porous materials such as glass wool, rock wool, and the like are well-known. However, glass wool, rock wool and the like have problems such as: having detrimental influences on the surrounding environment due to fibers, dust/patticles, and the like; decreasing sound-absorbing characteristics because of the influence of dust, humidity, chemicals, grease, and the like; and providing less freedom of beauty or less freedom in appearance because of external delustering or frosting.

[0004] Moreover, glass wool, rock wool, and the like are not generally used alone, and it is necessary to use them together with other materials such as clothes, nets, and the like having high permeability in order to improve their external appearance or to obtain durability; therefore, there is a problem in which beauty or the appearance is limited.

[0005] A sound-absorbing panel in which pierced apertures are provided on a plate member made from metal, wood, plastic, and the like, and in which a backside air layer is provided on an opposite side against a sound source, is well-known. However, with respect to such a sound absorbing panel, a diameter of the pierced aperture is comparatively large and can be seen by the naked eye; therefore, there is a problem in which beauty or the appearance is lessened. Moreover, similar to glass wool, rock wool, and the like, it is necessary to use them together with other materials such as clothes, nets, and the like having high permeability; therefore, there is a problem in which beauty or the appearance is limited.

[0006] On the other hand, a sound-absorbing panel which has pierced apertures of a few hundred micrometers in diameter is well-known (for example, Japanese Patent Application, First Publication No. 2005-173398); however, the pierced apertures of this sound-absorbing panel are provided by perforating with a drill, by applying a lithography technique, and the like; therefore, there is a problem in which production cost is high. Moreover, there is a problem in which the thicker the panel is, the larger the aspect ratio of the pierced aperture is; therefore, it is difficult to produce the sound-absorbing panel that has large thickness.

[0007] There are proposals which are still being studied such as applying a porous metal plate obtained by a well-known sintering process, that is, loosely coupling metallic powders, or by a well-known foaming process, that is, foaming by blowing gas into the melted metal, to the sound-absorbing material.

[0008] However, with respect to the above-described porous plate, there are multiple air holes inside, but since directions of the air holes are not equally directed along a thickness direction of the plate, there is a possibility in which it is hard for the holes that have one or both ends closed to be pierced apertures. Moreover, the air holes are easily blocked or closed because of burrs, modifications, and the like upon slicing; therefore, since a percentage of voids is not equal to an aperture ratio when it is sliced, it is difficult to control the aperture ratio, and there is a problem in which the sound-absorbing characteristics of the products are uneven and vary.

[0009] Moreover, there is a well-known method for obtaining a porous metal object in which metallic powder and salt in a powdered state are mixed, only the metallic powder is melted by heat, and after that, only the salt is removed after cooling down. However, in the porous metal object made in accordance with this method, empty holes which have a three-dimensional meshwork structure are formed, directions of the empty holes are not equally directed along a direction of the board thickness, a percentage of voids is not equal to an aperture ratio when it is sliced, it is difficult to control the aperture ratio, and there is a problem in which the sound-absorbing characteristics of the products are uneven and vary.

SUMMARY OF THE INVENTION

[0010] With respect to the above-described problems, the present invention was devised in order to achieve an object of providing a sound-absorbing material which has excellent characteristics of beauty or the appearance and of sound-absorbing, a production method of the same and a sound-absorbing panel including the sound-absorbing material.

[0011] In the present invention, in order to achieve the above-described object, the following constitutions are applied.

[0012] A sound-absorbing material of the present invention is characterized by comprising: a plate-shaped member made from a metal; and a plurality of pierced apertures of 200μm or smaller diameter provided on the plate-shaped member, and arranged along a board thickness direction of the plate-shaped member.

[0013] A sound-absorbing material production method of the present invention is characterized by comprising the steps of: mixing a metallic powder and a pierced aperture forming agent powder; forming a bulk body by solidifying and forming both the metallic powder and the pierced aperture forming agent powder along with drawing or drafting in a direction in a fibrous state; forming a plate-shaped member by slicing the bulk body along an orthogonal direction to a drawn or drafted direction; and forming a plurality of pierced apertures of a 200μm or smaller in diameter by removing the pierced aperture forming agent from the plate-shaped member.

[0014] A sound-absorbing material of the present invention is made by applying the above-described sound-absorbing material production method.

[0015] With respect to a sound-absorbing material of the present invention, an aperture ratio of the pierced apertures may preferably be in a range of 10-80%.

[0016] With respect to a sound-absorbing material production method of the present invention described above, a mixture of both the metallic powder and the pierced aperture forming agent powder may preferably be extruded by applying a hot extrusion method upon forming the bulk body. This hot extrusion method may preferably be conducted by applying a temperature at which the metallic powder and the pierced aperture forming agent powder are melted, or lower.

[0017] With respect to a sound-absorbing material production method of the present invention described above, the metallic powder may preferably be one of Al, Mg, Sn or Cu, an alloy made from one of these metals as a main raw material, or a mixed powder of one of these metallic powders and the alloy, and it may especially preferably be Al.

[0018] With respect to a sound-absorbing material production method of the present invention described above, the pierced aperture forming agent may preferably be made from a water-soluble salt, and NaCl may especially be preferable.

[0019] A sound-absorbing panel of the present invention may be characterized by comprising: two or more above-described sound-absorbing materials arranged at relatively sliding positions with a predetermined interval therebetween; and one or more air layers arranged between the sound-absorbing materials.

[0020] A sound-absorbing panel of the present invention may be characterized by comprising: a sound-absorbing material described above; a rigid body arranged at a relatively sliding position from the sound-absorbing material with a predetermined interval therebetween; and an air layer arranged between the sound-absorbing material and the rigid body.

[0021] A sound-absorbing panel of the present invention described above may preferably further comprise a porous sound-absorbing material arranged at the air layer. As the porous sound-absorbing material, for example, it is possible to apply a glass wool, a rock wool, and the like.

[0022] A sound-absorbing panel of the present invention described above may preferably further comprise a reinforcing member attached to a side of the air layer of the sound-absorbing material.

[0023] In accordance with the sound-absorbing material of the present invention, multiple pierced apertures which are 200μm or smaller and which are directed along the thickness direction of the board member; therefore, it is possible to improve the sound-absorbing characteristic. Moreover, the diameter of the pierced aperture is 200μm or shorter; therefore, the pierced aperture is not conspicuous and does not give unpleasant effects on beauty.

[0024] Moreover, in accordance with the sound-absorbing material of the present invention, a bulk object is formed by solidifying and shaping both the metallic powder and the pierced aperture forming agent powder along with being extended toward one direction in a fiber state, and the pierced aperture is formed by removing the pierced aperture forming agent powder after this bulk object is sliced in a board state along a perpendicular direction to the extending direction; therefore, there is less opportunity in which one end or both ends of the pierced aperture are blocked or closed. Therefore, it is possible to constitute the sound-absorbing material which provides the pierced apertures which have a large aspect ratio and which extend along a direction of the board thickness. Such the sound-absorbing material has an excellent sound-absorbing characteristic.

[0025] Moreover, in accordance with the sound-absorbing material of the present invention, the aperture ratio or the opening ratio is set to be in a range from 10% to 80%; therefore, it is possible to ward off unstableness upon producing or reducing strength as a panel.

[0026] Moreover, in accordance with the sound-absorbing material production method of the present invention, a bulk object is formed by solidifying and shaping both the metallic powder and the pierced aperture forming agent powder along with drawing or drafting toward one direction in a fiber state, and the pierced aperture is formed by removing the pierced aperture forming agent after this bulk object is sliced in a board state along a perpendicular direction to the drawn or drafted direction; therefore, there is less opportunity in which one end or both ends of the pierced aperture are blocked or closed, and it is possible to produce the low-cost sound-absorbing material that provides the pierced apertures which extend along a direction of the board thickness and which have a large aspect ratio. Moreover, it is possible to apply larger board thickness (length of the pierced aperture) to the sound-absorbing material. Such the sound-absorbing material has an excellent sound-absorbing characteristic.

[0027] Moreover, in accordance with the sound-absorbing panel of the present invention, a pair of the sound-absorbing materials or a sound-absorbing material and a rigid body are arranged so as to face each other, and an air layer is provided between a pair of the sound-absorbing materials or between the sound-absorbing material and the rigid body; therefore, it is possible to constitute a so-called Helmholtz resonator from the pierced apertures of the sound-absorbing material and the air layer, and it is possible to significantly increase the sound-absorbing characteristic. Moreover, the sound-absorbing material itself has an excellent beauty; therefore, it is possible to increase beauty of the sound-absorbing panel itself.

[0028] Moreover, in accordance with the sound-absorbing panel of the present invention, in the air layer between the sound-absorbing material and the rigid body, a porous sound-absorbing material is arranged therein; therefore, it is possible to further improve the sound-absorbing characteristic.

[0029] Moreover, in accordance with the sound-absorbing panel of the present invention, a reinforcing member is attached to a side of the air layer of the sound-absorbing material; therefore, it is possible to improve strength of the sound-absorbing material itself and to achieve a larger panel surface of the sound-absorbing panel.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030]

FIG. 1 is an oblique perspective view of a sound-absorbing material of an embodiment of the present invention.

FIG. 2 is a partial cross-sectional schematic view of the sound-absorbing material shown in FIG. 1.

FIG. 3 is a cross-sectional schematic view showing one example of a sound-absorbing panel of an embodiment of the present invention.

FIG. 4 is a cross-sectional schematic view showing another example of a sound-absorbing panel of an embodiment of the present invention.

FIG. 5 is a cross-sectional schematic view showing another example of a sound-absorbing panel of an embodiment of the present invention.

FIG. 6 is a cross-sectional schematic view showing another example of a sound-absorbing panel of an embodiment of the present invention.

FIG. 7 is a flowchart for explaining a production method of the sound-absorbing material of the embodiment of the present invention.

FIGS. 8A-8C are schematic views for explaining one step of a production method of the sound-absorbing material of the embodiment of the present invention.

FIG. 9 is a waveform chart showing a sound-absorbing characteristic of the sound-absorbing panel of the first embodiment of the present invention, and is a graph showing a frequency-dependent characteristic of a sound-absorption coefficient.

FIG. 10 is a waveform chart showing a sound-absorbing characteristic of the sound-absorbing panel of the first embodiment of the present invention, and is a graph showing a frequency-dependent characteristic of a sound-absorption coefficient in a case in which glass wool is filled in a backside air layer.

DETAILED DESCRIPTION OF THE INVENTION

[0031] Hereinafter, referring to drawings, an embodiment of the present invention is explained. It should be noted that the drawings which are referred to below are used for explaining a sound-absorbing material and production methods of both a sound-absorbing panel and the sound-absorbing material; therefore, there is a possibility of the size, thickness, and the like of each portion shown in drawings being different from actual or real size of the sound-absorbing material and the like.

"Sound-absorbing material"

[0032] Hereinafter, referring to FIG. 1 and FIG. 2, a sound-absorbing material of this embodiment is explained. FIG. 1 is an oblique perspective view of the sound-absorbing material of this embodiment, and FIG. 2 is a cross-sectional schematic view of a portion of the magnified sound absorbing material shown in FIG. 1.

[0033] As shown in FIG. 1, a sound-absorbing material 1 of this embodiment is constituted from a plate-shaped member 2 which is made from a metal, and is produced in accordance with a production method explained below. This plate-shaped member 2 has a surface 2a and another surface 2b which have the largest area of all surfaces that are external surfaces of the plate-shaped member. The surface 2a and the surface 2b are facing each other along with being arranged along a thickness direction of the plate-shaped member 2. On these surfaces 2a and 2b, as shown in FIG. 2, multiple pierced apertures 3 are provided. On the other hand, an area on the surfaces 2a and 2b on which the pierced apertures 3 are not provided is a metal surface 2c.

[0034] It is preferable for the plate-shaped member 2 to be made from a metal, to be one of Al, Mg, Sn or Cu, or an alloy mainly made from one of these metals, or to be a mixed object of both these metals and the alloy, and Al is especially preferable.

[0035] A thickness t of the plate-shaped member 2 is preferably in a range from 0.5mm to 10mm, and a range from 1mm to 5mm is further preferable. It should be noted that the thickness t of the plate-shaped member 2 corresponds to a length of the pierced aperture along the board thickness direction. If the thickness t of the plate-shaped member 2 (length of the pierced aperture) is 0.5mm or larger, it is preferable because there is no possibility of the strength of the plate-shaped member 2 decreasing and the sound-absorbing characteristic dropping. Moreover, if the thickness t of the plate-shaped member 2 (length of the pierced aperture) is 10mm or less, there is no possibility of one or both ends of the pierced aperture 3 being closed or blocked and the sound-absorbing characteristic dropping.

[0036] As shown in FIG. 2, the pierced aperture 3 exists along with extending along the board thickness direction of the plate-shaped member 2, and pierces through the plate-shaped member 2. With respect to a shape of the pierced aperture 3 seen on a surface, a circular shape is preferable; however, an oval shape, a rectangular shape or a polygon with rounder angles is possible. Moreover, it is possible to have a portion of pierced apertures which have uneven or irregular shapes seen on the surface because neighboring pierced apertures 3 are connected or mixed.

[0037] A diameter d of the pierced aperture 3 (a diameter of an equivalent circle corresponding to an area of a cross-section of the aperture) can be in a range of 200μm or less, preferably the range is from 10μm to 200μm, and more preferably, the range is from 50μm to 200μm. If the diameter d is smaller than 50μm, it is difficult to remove the pierced aperture forming agent. Moreover it is possible that the diameters d of the pierced apertures 3 be respectively different.

[0038] If the diameter d is larger than 200μm, it is easy to see the pierced aperture 3 by the naked eye and beauty or the appearance of the sound-absorbing material 1 is decreased; therefore, it is not preferable.

[0039] It is preferable that the shape of the pierced aperture 3 seen on the surface and its size be constant along the thickness direction of the plate-shaped member 2; however, it is possible that the size be gradually changed along the thickness direction of the plate-shaped member 2. In other words, with respect to the pierced aperture 3 shown in FIG. 2, the shape seen on the surface and its size are respectively constant along the thickness direction of the plate-shaped member 2, and there is a relationship in which the wall surface 3a of the pierced aperture 3 is crossing the surfaces 2a and 2b at a right angle; however, it is possible that the wall surface of the pierced aperture 3 be a tapered surface.

[0040] It is preferable that an aperture ratio s of the pierced apertures 3 be set to be in a range from 10% to 80%, and the range is preferably from 20% to 60%. The aperture ratio s of the pierced apertures 3 is a ratio of the opening area of the pierced apertures 3 to the area of the surface 2a or the surface 2b. If the aperture ratio s is 10% or more, there is no possibility of decreasing the sound-absorbing characteristics caused by a lack of the pierced apertures 3, and it is easy to remove the pierced aperture forming agent in a production step described later. Moreover, if the aperture ratio s is 80% or less, there is no possibility of connecting the pierced apertures 3 to each other, and it is possible to obtain sufficient strength of the sound-absorbing material 1.

[0041] It is preferable that the above-described sound-absorbing material 1 be arranged so as to set the surface 2a or 2b to face a position of a sound source. The surface which is on an opposite side of the sound-absorbing material 1 against the position of the sound source is exposed to an air layer, and this air layer and the pierced apertures 3 of the sound-absorbing material 1 are connected so as to form a so-called Helmholtz resonator; therefore, it is possible to obtain a sound-absorbing ability

[0042] A sound-absorbing ability of the Helmholtz resonator is determined in accordance with the thickness t of the plate-shaped member 2 (length of the pierced aperture), the diameter d of the pierced aperture 3, intervals, gaps or distances among the pierced apertures 3, and the like; therefore, it is possible to determine appropriate settings within the above-described most preferable ranges in order to obtain the maximum sound-absorbing ability in accordance with acoustic characteristics such as frequency of the sound aimed to be absorbed.

[0043] In a practical case, it is possible to set the thickness t of the plate-shaped member 2 (length of the pierced aperture), the diameter d of the pierced aperture 3 and the aperture ratio s of the pierced apertures 3 so as to enlarge a maximum sound-absorbing ratio a_0, which is explained in a document (Dah-You Maa,"Potential of microperforated panel absorber", J.Acoust.Soc.Am.,Yo1.104, No.5, November, 1998). It should be noted that there is a relationship in which r in a formula (1) is calculated in accordance with a formula (2), k_r in the formula (2) is calculated in accordance with a formula (3), and k in the formula (3) is calculated in accordance with a formula (4). Moreover, in the formulas (1)-(4), t is a thickness of the plate-shaped member 2, d is a diameter of the pierced aperture 3, s is an aperture ratio of the pierced aperture 3, η is a viscosity of air, ρ_0 is a density of the air, c is a speed of sound in the air, and ω is an angular frequency.

$$a_0 = 4r/(1+r)2 \ldots (1)$$

$$r = (32\eta t/s \rho_0 c d^2)k_r \ldots (2)$$

$$k_r = (1+k^2/32)^{1/2}+(2^{1/2}d/32t)k \ldots (3)$$

$$k = d(\omega\rho_0/4\eta)^{1/2} \ldots (4)$$

[0044] As explained above, in accordance with the sound-absorbing material 1 of this embodiment, multiple pierced apertures 3 are provided which are 200μm or smaller and which are directed along the thickness direction of the board member 2; therefore, it is possible to improve the sound-absorbing characteristics. Moreover, the diameter of the pierced aperture is 200μm or smaller; therefore, the pierced apertures 3 are not conspicuous and do not adversely affect beauty or the appearance.

[0045] Moreover, in accordance with the above-described sound-absorbing material 1, the aperture ratio of the pierced apertures 3 is in a range from 10% to 80%; therefore, it is possible to achieve excellent sound absorbing characteristics.

"Sound-absorbing panel"

[0046] Hereinafter, referring to FIG. 3-6, a sound-absorbing panel including the above-described sound-absorbing material is explained.

[0047] FIG. 3 is a cross-sectional schematic view showing one example of the sound-absorbing panel of an embodiment.

[0048] A sound-absorbing panel 10 shown in FIG. 3 is formed from a pair of the above-described sound-absorbing materials 1A(1) and 1B(I) which are arranged so as to face each other with a predetermined interval in between. By separating the sound-absorbing materials 1A and 1B upon arranging them, an air layer 11 is provided between the sound-absorbing materials 1A and 1B. The air layer 11 is provided between the sound-absorbing materials 1A and 1B, and the air layer 11 and the pierced apertures 3 of the sound-absorbing material 1A and 1b are connected so as to form the so-called Helmholtz resonator. Therefore, it is possible to largely improve a sound-absorbing ability

[0049] An interval m1 between the sound-absorbing materials 1A and 1B, in other words, a thickness of the air layer 11 is preferably in a range from 5mm to 1000mm, and more preferably the range is from 50mm to 500mm. It is not possible to obtain preferable sound-absorbing characteristics if the thickness of the air layer 11 is out of this range.

[0050] The sound-absorbing panel 10 shown in FIG. 3 is provided with the sound absorbing materials 1A and 1B, which have the same constitution; therefore, it is possible to arrange one of the sound-absorbing materials 1A and 1B so as to face the sound source. It is possible to freely arrange a direction of the sound-absorbing panel 10 regardless of a position of the sound source upon executing or arranging; and therefore, freedom of execution or arrangement is improved.

[0051] FIG. 4 is a cross-sectional schematic view showing another example of a sound-absorbing panel.

[0052] A sound-absorbing panel shown in FIG. 4 has a constitution in which the above-described sound-absorbing material 1A and a rigid body 21 in a plate shape are facing each other so as to have a predetermined interval. By separating the sound-absorbing material 1A and the rigid body 21 upon arranging them, as described in FIG. 3, an air layer 22 is provided between the sound-absorbing material 1A and the rigid body 21. The air layer 22 is provided between the sound-absorbing materials 1A and the rigid body 21, and the air layer 11 and the pierced apertures 3 of the sound-absorbing material 1A are connected so as to form the so-called Helmholtz resonator. Therefore, it is possible to greatly improve a sound-absorbing ability.

[0053] An interval m2 between the sound-absorbing materials 1A and the rigid body 21, in other words, a thickness of the air layer 22 is preferably in a range from 5mm to 1000mm, and more preferably the range is from 50mm to 500mm. It is not possible to obtain preferable sound-absorbing characteristics if the thickness of the air layer 22 is out of this range.

[0054] With respect to the sound-absorbing panel 20 shown in FIG. 4, it is preferable to arrange the sound-absorbing material 1A so as to face the sound source. Therefore, the sound waves efficiently enter the pierced apertures 3 of the sound-absorbing material 1A, and it is possible to obtain excellent sound-absorbing characteristic.

[0055] FIG. 5 is a cross-sectional schematic view which shows another example of a sound-absorbing panel.

[0056] A sound-absorbing panel 30 shown in FIG. 5 has a constitution in which the above-described sound-absorbing material 1A and the rigid body 21 in a plate shape are facing each other so as to have a predetermined interval, and moreover, the constitution includes a porous sound-absorbing material 31 which is arranged between the sound-absorbing material 1A and the rigid body 21 (an air layer 22). As in FIGS. 3 and 4, by arranging the sound-absorbing material 1A and the rigid body 21 so as to have an interval, the air layer 22 is provided between the sound-absorbing material 1A and the rigid body 21. The air layer 22 is provided between the sound-absorbing material 1A and the rigid body 21, and the air layer 11 and the pierced apertures 3 of the sound-absorbing material 1A are connected so as to form the so-called Helmholtz resonator. Therefore, it is possible to greatly improve a sound-absorbing ability.

[0057] Moreover, the porous sound-absorbing material 31 is arranged at the air layer 22; therefore, it is possible to further improve the sound-absorbing characteristics of the sound-absorbing panel 30. As the porous sound-absorbing material 31, for example, it is possible to apply glass wool, rock wool and the like.

[0058] With respect to this sound-absorbing panel 30, an interval m3 between the sound-absorbing materials 1A and the rigid body 21, in other words, a thickness of the air layer 22 is preferably in a range from 5mm to 1000mm, and more preferably the range is from 50mm to 500mm. It is not possible to obtain preferable sound-absorbing characteristics if the thickness of the air layer 22 is out of this range.

[0059] With respect to the sound-absorbing panel 30 shown in FIG. 5, as in a case of the sound-absorbing panel 20 shown in FIG. 4, it is preferable to arrange the sound-absorbing material 1A so as to face the sound source. Therefore, the sound waves efficiently enter the pierced apertures 3 of the sound-absorbing material 1A, and it is possible to obtain excellent sound-absorbing characteristics.

[0060] FIG. 6 is a cross-sectional schematic view which shows another example of a sound-absorbing panel.

[0061] A sound-absorbing panel 40 shown in FIG. 6 has a constitution in which the above-described sound-absorbing material 1A and the rigid body 21 in a plate shape are facing each other so as to have a predetermined interval, and moreover, the constitution includes a reinforcing member 41 which is attached to a side of a surface 1a of the sound-absorbing material 1A (an air layer). It is possible to arrange an interval between the reinforcing member 41 and the rigid body 21 and to adhere the reinforcing member 41 and the rigid body 21. Moreover, it is possible to arrange the reinforcing member 41 at a side of the surface la, which is a side of the rigid body of the sound absorbing material 1A, or to arrange at an side of the surface 1b, which is an opposite side from the rigid body; however, from a point of view of improving beauty or the appearance of the sound-absorbing panel 40, it is preferable to arrange at a side of the surface 1a, which is a side of the rigid body 21 of the sound absorbing material 1A.

[0062] As the reinforcing member 41, it is possible to apply, for example, a member which includes intervals, gaps, vacant spaces or apertures such as: a honeycomb panel made from a metal such as aluminum; a panel in a grid or crib shape; a rib; and the like. In accordance with such a manner, there is no possibility in which the pierced aperture 3 and the air layer 22 are blocked or completely separated by the reinforcing member 41.

[0063] As in FIG. 3 to 5, by arranging the sound-absorbing material 1A and the rigid body 21 so as to have an interval, the air layer 22 is provided between the sound-absorbing material 1A and the rigid body 21. It should be noted that, with respect to the sound-absorbing panel 40 shown in FIG. 6, the gaps of the reinforcing member 41 and the air layer 22 are connected, and the gaps of the reinforcing member 41 are included as a portion of the air layer 22.

[0064] The air layer 22 is provided between the sound-absorbing materials 1A and the rigid body 21, and the so-called Helmholtz resonator is constituted from both the pierced apertures 3 of the sound-absorbing material 1A and the air layer 11. Therefore, it is possible to greatly improve a sound-absorbing ability

[0065] Moreover, the reinforcing member 41 is attached to the sound-absorbing material 1A; therefore, it is possible to improve the strength of the sound-absorbing material 1A itself

[0066] With respect to this sound-absorbing panel 40, an interval m4 between the sound-absorbing material 1A and the rigid body 21, in other words, a thickness of the air layer 22 is preferably in a range from 5mm to 1000mm, and more preferably the range is from 50mm to 500mm. It is not possible to obtain preferable sound-absorbing characteristics if the thickness of the air layer 22 is out of this range.

[0067] With respect to the sound-absorbing panel 40 shown in FIG. 6, as in cases of the sound-absorbing panels 20 and 30 shown in FIG. 4 and 5, it is preferable to arrange the sound-absorbing material 1A so as to face the sound source. Therefore, the sound waves efficiently enter the pierced apertures 3 of the sound-absorbing material 1A, and it is possible to obtain excellent sound-absorbing characteristics.

[0068] It should be noted that it is possible to attach the reinforcing member 41 not only to the sound-absorbing panel 40 shown in FIG. 6, but also to the sound absorbing material 1A of the sound absorbing panels 10, 20 and 30 shown in FIG. 3-5.

[0069] It is possible to attach the porous sound-absorbing material 31 not only to the sound-absorbing panel 30 shown in FIG. 5, but also to the sound absorbing panels 10, 20 and 40 shown in FIG. 3, 4 and 6.

[0070] In accordance with the sound-absorbing panels 10-40: the sound-absorbing material 1A and the sound-absorbing material 1B, or the sound-absorbing material 1A and the rigid body 21 are arranged so as to face each other; the air layer 11/22 is provided between the sound-absorbing material 1A and the rigid body 21; and the so-called Helmholtz resonator is constituted from both the pierced apertures 3 and the air layer 11/22; therefore, it is possible to greatly improve a sound-absorbing ability. Moreover, the sound-absorbing materials 1A and 1B themselves have excellent beauty or the appearance; therefore, it is possible to increase beauty or the appearance of the sound-absorbing panels 10-40 themselves.

"Production method of the sound-absorbing material"

[0071] A production method of the sound-absorbing material 1 of this embodiment is explained.

[0072] FIG. 7 shows a flowchart of the production method of the sound-absorbing material 1. As shown in FIG. 7, the production method of the sound-absorbing material 1 of this embodiment includes: a mixing step S1 in which metallic powder and powder of the pierced aperture forming agent are mixed; a hot extrusion step S2 in which a bulk body is solidified and formed along with drawing or drafting the metallic powder and the powder of the pierced aperture forming agent in one direction so as to be in a fibrous state; a slicing step S3 in which the bulk body is sliced in a plate state in a direction perpendicular to the drawing or drafting direction; and a pierced aperture forming agent removing step S4 in which the pierced apertures are formed by removing the pierced aperture forming agent.

[0073] Hereinafter, each of the steps is explained.

(Mixing step S1)

[0074] In the mixing step S1, mixed powder is manufactured by mixing both the metallic powder and the powder of the pierced aperture forming agent. As a mixing method, it is possible to apply well-known conventional methods.

[0075] As the metallic powder, it is possible to apply one of Al, Mg, Sn or Cu, or an alloy mainly made from one of these metals, or to apply a mixed powder of these metallic powders and the alloy; however, Al is especially preferable because of a point of view such as lightness, corrosion resistance, ease of processing, cost of the material, and the like. Moreover, as the metallic powder, it is preferable to apply the metallic powder with an average particle diameter in a range of 30-1000μm from the viewpoint that the metallic powder is processed into a fibrous state in the hot extrusion step S2 described below. And furthermore, it is preferable to make the particle diameter of all the metallic powder to be in a range of 10-2000μm.

[0076] As the pierced aperture forming agent, it is preferably made from water-soluble salts, NaCl or KCl is more preferable, and NaCl is especially preferable. Such pierced aperture forming agents have a high melting point; and therefore, it is possible to process into the fibrous state along with avoiding reaction with the metallic powder in the hot extrusion step S2 described below. Moreover, these pierced aperture forming agents are water-soluble; therefore, it is possible to easily remove them in the pierced aperture forming agent removing step explained below. It should be noted that the pierced aperture forming agent is not limited to the above-explained materials, and it is possible to apply any material which can be drawn or drafted in one direction and be formed in a fibrous state by processing such as a hot extrusion and which can be easily removed.

[0077] On the other hand, it is preferable to apply a powder of the pierced aperture forming agent with an average particle diameter in a range of 50-1000μm. And furthermore, it is preferable to make the particle diameter of the powder of the pierced aperture forming agent to be in a range of 30-2000μm. If the diameter of the powder is smaller than a lower limit of this range, after extrusion, the pierced aperture forming agent becomes too narrow, in other words, the aperture diameter is too small; therefore, it is difficult to remove the pierced aperture forming agent. On the other hand, if the diameter of the powder is larger than an upper limit of this range, a larger extrusion ratio is needed in the extrusion step, and the extrusion pressure is larger; therefore, a stronger metallic mold and a larger apparatus are needed (it causes a larger cost).

[0078] It should be noted that the average particle diameters and the range of the particle diameters of the metallic powder and the powder of the pierced aperture forming agent are preferably as described above; however, they are not limited as described above, and it is possible to set them in a range in which the diameter of the pierced apertures is set to be 200μm or smaller in accordance with a processing condition, especially a combination with the extruding ratio.

[0079] A mixing ratio of the metallic powder and the powder of the pierced aperture forming agent is preferably in a range of "the metallic powder: the powder of the pierced aperture forming agent = 90:10 to 20:80" by volume, and moreover, a range of "80:20 to 40:60" is especially preferable. The mixing ratio of the metallic powder and the powder of the pierced aperture forming agent is adjusted in the above-described range; therefore, it is possible to control the aperture ratio of the sound absorbing material. If the ratio of the pierced aperture forming agent is decreased, there is a possibility in which the pierced apertures are not sufficiently formed, and in which the aperture ratio is lower. Furthermore, if the ratio of the pierced aperture forming agent is increased, there is a possibility in which the diameter of the pierced aperture is increased and it is difficult to adjust it so as to be 200μm or smaller, and in which the aperture ratio is increased.

(Hot extrusion step S2)

[0080] In the hot extrusion step S2, a hot extrusion operation is conducted on the above-described mixed powder, and a bulk body is solidified and formed along with drawing or drafting the metallic powder and the powder of the pierced aperture forming agent in one direction so as to be in a fibrous state. With respect to conditions of the hot extrusion step, it is preferable to apply a range of 3-500 as an extrusion ratio, and if Al is used as the metallic powder, it is preferable to set the extrusion temperature in a range from 300°C to 600°C. If the condition is out of this range, it is difficult to form the bulk body.

[0081] It should be noted that it is not needed to conduct extrusion when it is hot, and if it satisfies a condition in which the bulk body is solidified and formed along with drawing or drafting the metallic powder and the powder of the pierced aperture forming agent so as to be in a fibrous state, it is possible to apply a cold extrusion.

[0082] By applying such hot extrusion, the metallic particles of the metallic powder are associated because of the influence of pressure and temperature, and the associated metal is extruded along a drawn or drafted direction in a fibrous state. The powder of the pierced aperture forming agent is integrated because of the influence of pressure and temperature, and is extruded along the extruded direction in a fibrous state or the particle itself is extruded along the drawn or drafted direction in a fibrous state. Both the drawn metal in a fibrous state and the drawn pierced aperture forming agent in a fibrous state are integrated and are formed and solidified so as to be a bulk body as a whole. On a cross-section which orthogonally crosses the extruded direction of the bulk body, both the drawn metal in a fibrous state and the drawn pierced aperture forming agent in a fibrous state are distributed in a mosaic state. It should be noted that the drawn direction of the fiber of the bulk body formed in the hot extrusion step is the same as the extruded direction.

(Slicing step S3)

[0083] In the slicing step S3, the above-described bulk body is sliced along an orthogonal direction to the drawn or drafted direction (extruded direction) so as to be a plate shape. FIG. 8 is a schematic diagram which shows the slicing step.

[0084] FIG. 8A is a schematic diagram of a cross-section of a bulk body 50. In FIG. 8A, multiple parallel lines drawn on the cross-section of the bulk body 50 are a pierced aperture forming agent 51 drawn or drafted in a fibrous state. This pierced aperture forming agent 51 is drawn or drafted in a fibrous state along the same direction as the extruded direction.

[0085] In FIG. 8B, the bulk body 50 is sliced along a direction orthogonal to the extruded direction. In FIG. 8B, dashed lines are lines indicate sliced surface. In this embodiment, it is preferable to arrange the extruded direction and the sliced surfaces (sliced direction) so as to respectively cross orthogonally. After slicing, the pierced aperture forming agent 51 is exposed on the sliced surface, and a plate-shaped member 2d as shown in FIG. 8C is obtained.

(Pierced aperture forming agent removing step S4)

[0086] In the pierced aperture forming agent removing step S4, the pierced apertures are obtained by removing the pierced aperture forming agent 51 from the plate-shaped member 2d. As a removing method, it is possible to apply a method of eluting or volatilizing the pierced aperture forming agent. Especially, if the water-soluble salt is used as the pierced aperture forming agent, it is preferable to apply an elution method. In a concrete case, it is possible to elute the pierced aperture forming agent 51 from the plate-shaped member 2d by soaking the bulk body in water and leaving it for 1-24 hours. In such a manner, the sound-absorbing material 1 of this embodiment can be obtained.

[0087] After conducting the slicing step, a sliced surface of the plate-shaped member 2d becomes surfaces 2a and 2b of the plate-shaped member 2 which constitute the sound-absorbing material 1. Therefore, there is a relationship of orthogonally crossing between the surfaces 2a/2b of the sound-absorbing material 1 and the extruded direction. On the other hand, the pierced apertures 3 are formed after conducting both the slicing step and the pierced aperture forming agent removing step, and the pierced aperture 3 is formed by removing the pierced aperture forming agent 51; therefore, the pierced aperture 3 extends along the same direction as the extruded direction. In accordance with above explanation, the pierced apertures 3 provided on the sound-absorbing material 1 have a relationship of orthogonally crossing with the surfaces 2a and 2b. Therefore, if the surface 1a or 1b is arranged so as to face the sound source when the sound-absorbing material 1 is set after production, a relationship can be obtained in which the sound source is positioned on an extending direction of the pierced aperture 3; therefore, it is possible to mostly and effectively exert or use the sound-absorbing characteristics of the sound-absorbing material 1.

[0088] In accordance with the above-described production method of the sound-absorbing material 1, the bulk object is formed by solidifying and shaping both the metallic powder and the pierced aperture forming agent powder along with extending toward one direction in a fibrous state, and the pierced apertures 3 are formed by removing the pierced aperture forming agent after this bulk object is sliced in a board state along a perpendicular direction to the extending direction; therefore, there is less chance of one end or both ends of the pierced apertures 3 being blocked or closed, and it is possible to produce the low-cost sound-absorbing material 1 that provides the pierced apertures 3 which extend along a direction of the board thickness and which have a large aspect ratio. Moreover, it is possible to enlarge the board thickness of the sound-absorbing material 1. Such the sound-absorbing material 1 has excellent sound-absorbing characteristics.

[0089] With respect to the sound-absorbing material 1 made in accordance with the above-described production, the pierced apertures 3 are formed by slicing the bulk body in a plate shape along an orthogonal direction against the extruded direction; therefore, there is less chance of one end or both ends of the pierced apertures 3 being blocked or closed, and it is possible to produce the sound-absorbing material 1 that provides the pierced apertures 3 which extend along a direction of the board thickness and which have a large aspect ratio. Such a sound-absorbing material 1 has excellent sound-absorbing characteristics.

[Examples]

(First example)

[0090] A mixed powder was obtained in a manner in which both NaCl powder (pierced aperture forming agent) with an average particle diameter of 420μm and Al powder (metallic powder) with an average particle diameter of 200μm were mixed with a mixing ratio of "the metallic powder: the powder of the pierced aperture forming agent = 55:45" by volume.

[0091] A bulk body was formed by conducting the heat extrusion operation upon the obtained mixed powder in a condition in which an extrusion ratio was 6.9 and an extrusion temperature was 450°C. The obtained bulk body was sliced in a direction orthogonally crossing against an extrusion direction, and a plate-shaped member was obtained. NaCl was soaked by soaking the plate-shaped member in water for 6 hours, and a sound-absorbing material of the first example was produced

[0092] With respect to the sound-absorbing material of the first example, many pierced apertures with an average diameter of approximately 100μm were recognized upon observing with a scanning electron microscope. On the other hand, an aperture ratio was 45% in accordance with a calculation based on the mixing ratio of the pierced aperture forming agent and the metallic powder.

[0093] Normal incidence sound absorption characteristics of the sound-absorbing material of the first example were measured by applying a transfer function method (in conformity with ISO 10534-2). As concrete conditions, the sound-absorbing material of the first example was arranged at one end of a sound tube in a hollow or empty cylindrical shape of 400mm length and 40mm inside diameter, and a backside air layer was 150mm. A rigid body was arranged at an opposite side of the backside air layer of the sound-absorbing material. A speaker was arranged at an opposite end of the sound tube. Moreover, two microphones were arranged between both ends of the sound tube so as to obtain a predetermined interval or gap therebetween. The speaker and the microphones were respectively connected to calculation apparatuses for measuring. In such a manner, a measuring apparatus of the normal incidence sound absorption characteristics by applying the transfer function (in conformity to ISO 10534-2) was constituted.

[0094] Sound of a certain band was emitted from the speaker, the transfer function between the two microphones provided inside the tube was measured, and the normal incidence sound absorption coefficient was calculated based on this transfer function.

[0095] FIG. 9 shows the results. It should be noted that, in FIG. 9, calculated values of the normal incidence sound absorption coefficient obtained by applying the above-described formula (1) are shown as well.

[0096] As shown in FIG. 9, measured values correspond to calculated values very well, and it can be seen that excellent sound-absorbing characteristics were obtained.

[0097] Moreover, as in the above description, the same conditions were applied except that glass wool was filled in the backside air layer of 150mm thickness between the sound-absorbing material of the first example and the rigid body, and the normal incidence sound absorption characteristics of the sound-absorbing material of the first example were measured by applying a transfer function method (in conformity with ISO 10534-2),. The results are shown in FIG. 10. It should be noted that the measurement results of the sound-absorbing panel of FIG. 9 are shown in FIG. 10 as well.

[0098] As shown in FIG. 10, in a case of filling the glass wool in the backside air layer, compared to a case of filling no glass wool, a frequency band which shows the sound-absorbing ratio of 0.8 or larger is extended, and it can be seen that the sound-absorbing characteristics are further improved. It is supposed that such an extension of the frequency band is caused by filling the glass wool in the air layer.

(First comparative example)

[0099] The sound-absorbing material of the first comparative example is produced by piercing multiple pierced apertures of 200μm diameter with a 200μm pitch on an aluminum plate of 1mm thickness by using a drill. It should be noted that the pierced apertures are arranged so as to be in a grid state.

[0100] The conditions are the same as the first example except for using the sound-absorbing material of the first comparative example, and the normal incidence sound absorption coefficient was measured. Almost the same sound-absorbing characteristics as the first example were obtained.

[0101] However, the pierced apertures were formed with a drill upon producing the sound-absorbing material of the first comparative example; therefore, it took a long time for producing the sound-absorbing material.

[0102] While preferred embodiments of the invention have been described and illustrated above, it should be understood that these are exemplary of the invention and are not to be considered as limiting. Additions, omissions, substitutions, and other modifications can be made without departing from the spirit or scope of the present invention. Accordingly, the invention is not to be considered as being limited by the foregoing description, and is only limited by the scope of the appended claims.

Claims

1. A sound-absorbing material comprising:

a plate-shaped member made from a metal; and
a plurality of pierced apertures of 200μm or smaller diameter provided on the plate-shaped member, and arranged along a board thickness direction of the plate-shaped member.

2. A sound-absorbing material production method comprising the steps of:

mixing a metallic powder and a pierced aperture forming agent powder;
forming a bulk body by solidifying and forming both the metallic powder and the pierced aperture forming agent powder along with drawing or drafting in a direction in a fibrous state;
forming a plate-shaped member by slicing the bulk body along an orthogonal direction to a drawn or drafted direction; and
forming a plurality of pierced apertures of a 200μm or smaller in diameter by removing the pierced aperture forming agent from the plate-shaped member.

3. A sound-absorbing material made by applying the sound-absorbing material production method according to claim 2.

4. A sound-absorbing material according to claim 1, wherein an aperture ratio of the pierced apertures is in a range of 10-80%.

5. A sound-absorbing material production method according to claim 2, wherein a mixture of both the metallic powder and the pierced aperture forming agent powder is extruded by applying a hot extrusion method upon forming the bulk body.

6. A sound-absorbing material production method according to claim 2, wherein the metallic powder is one of Al, Mg, Sn or Cu, an alloy made from one of these metals as a main raw material, or a mixed powder of one of these metallic powders and the alloy.

7. A sound-absorbing material production method according to claim 2, wherein the pierced aperture forming agent is made from a water-soluble salt.

8. A sound-absorbing panel comprising:

two or more sound-absorbing materials according to claim 1 arranged at relatively sliding positions with a predetermined interval therebetween; and
one or more air layers arranged between the sound-absorbing materials.

9. A sound-absorbing panel comprising:

a sound-absorbing material according to claim 1;
a rigid body arranged at a relatively sliding position from the sound-absorbing material with a predetermined interval therebetween; and
an air layer arranged between the sound-absorbing material and the rigid body.

10. A sound-absorbing panel according to claim 8, further comprising a porous sound-absorbing material arranged at the air layer.

11. A sound-absorbing panel according to claim 9, further comprising a porous sound-absorbing material arranged at the air layer.

12. A sound-absorbing panel according to claim 8, further comprising a reinforcing member attached to a side of the air layer of the sound-absorbing material.

13. A sound-absorbing panel according to claim 9, further comprising a reinforcing member attached to a side of the air layer of the sound-absorbing material.

FIG. 1

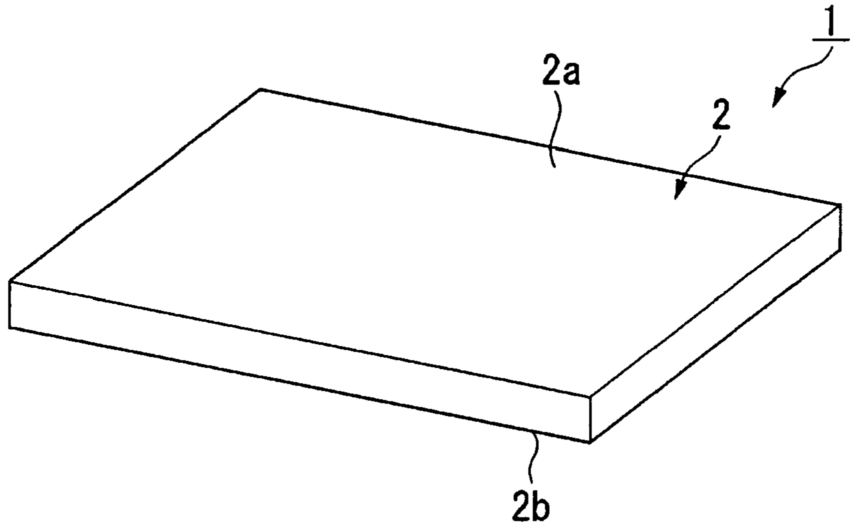


FIG. 2

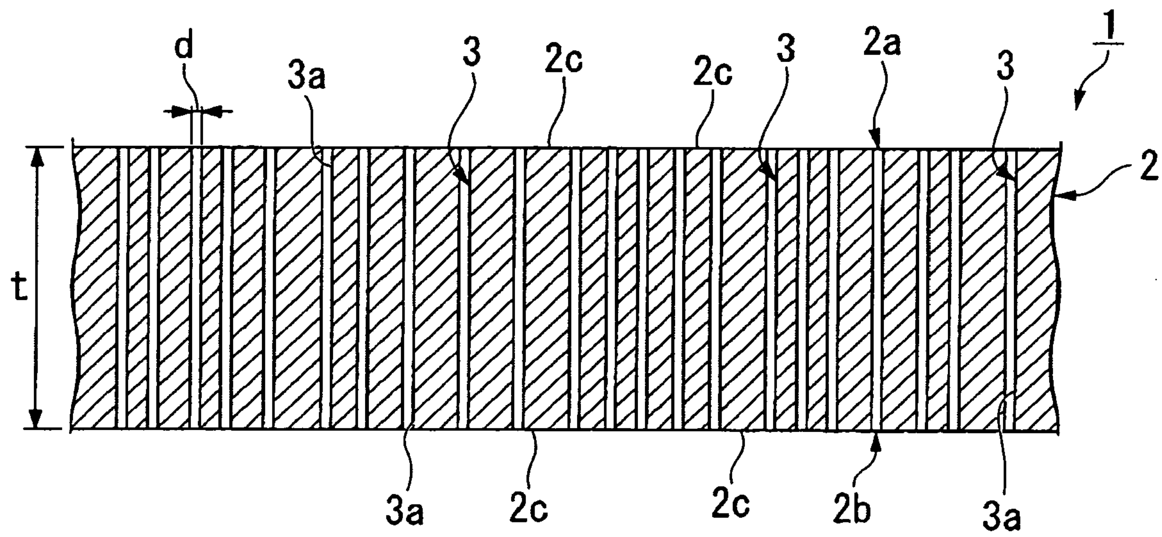


FIG. 3

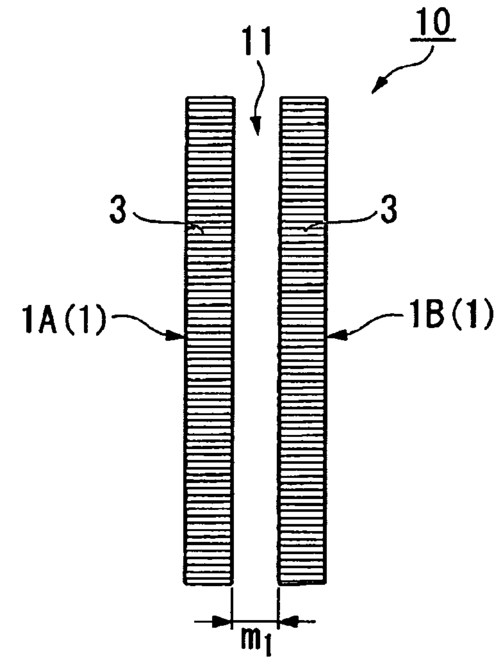


FIG. 4

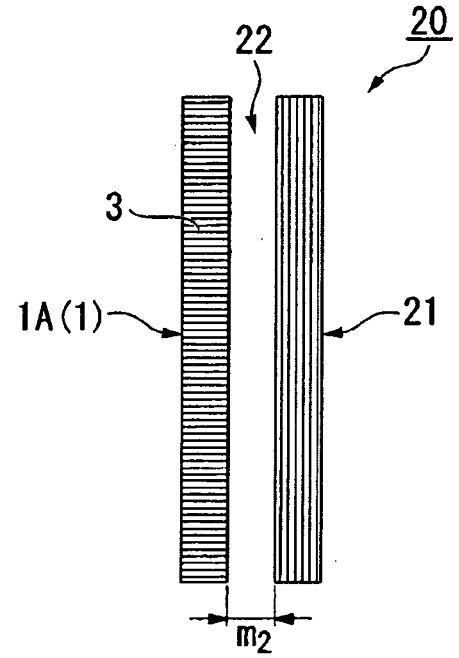


FIG. 5

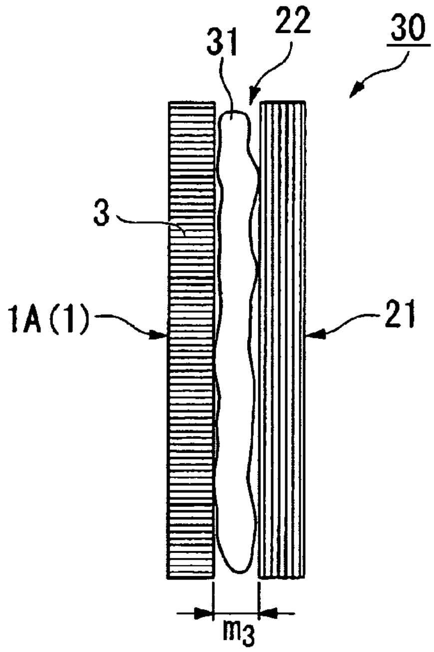


FIG. 6

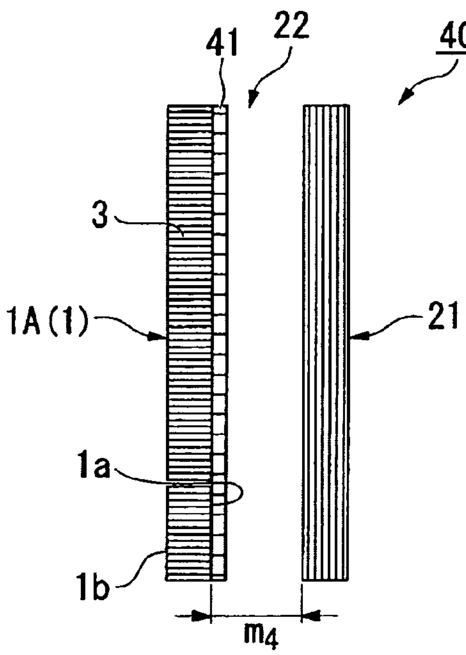


FIG. 7

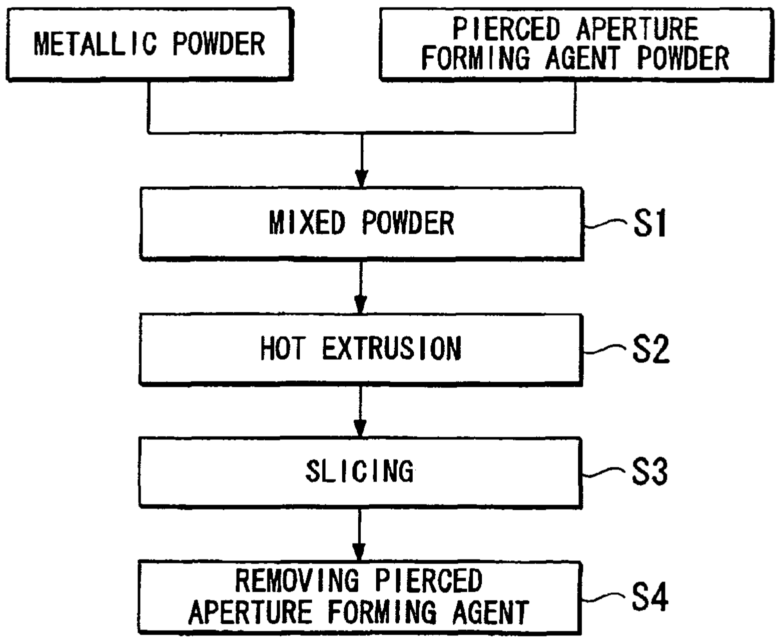
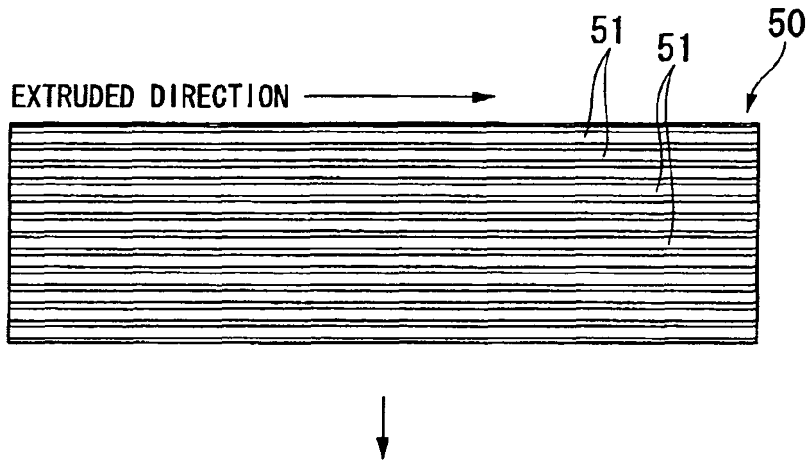
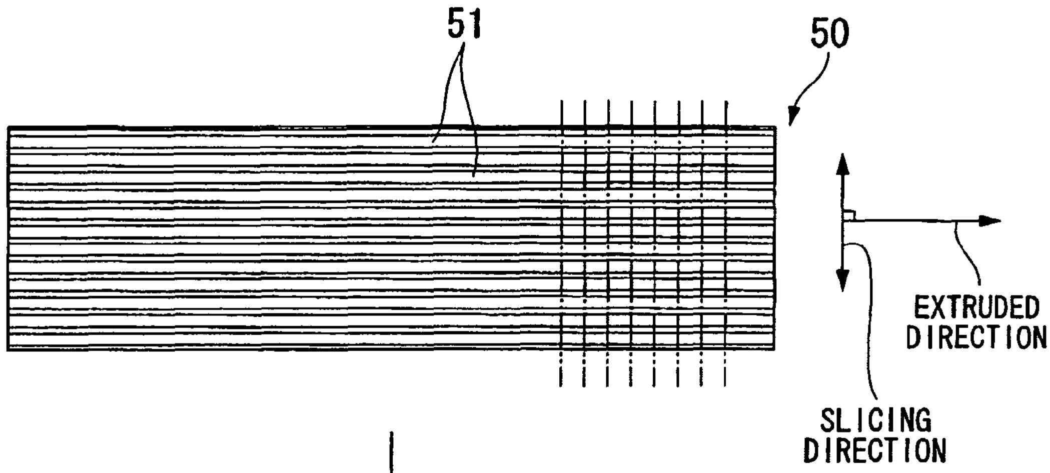


FIG. 8A



To FIG. 8B

FIG. 8B



To FIG. 8C

FIG. 8C

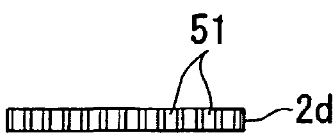


FIG. 9

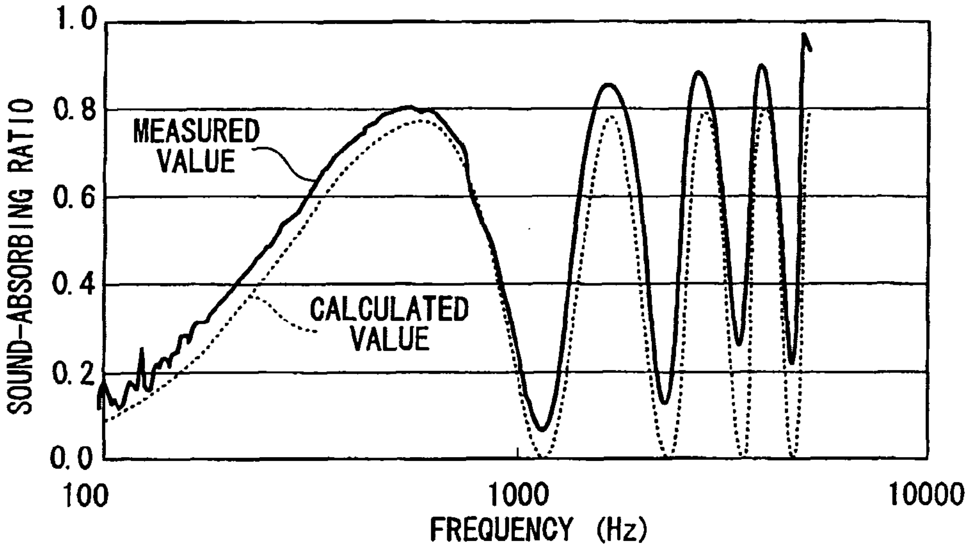
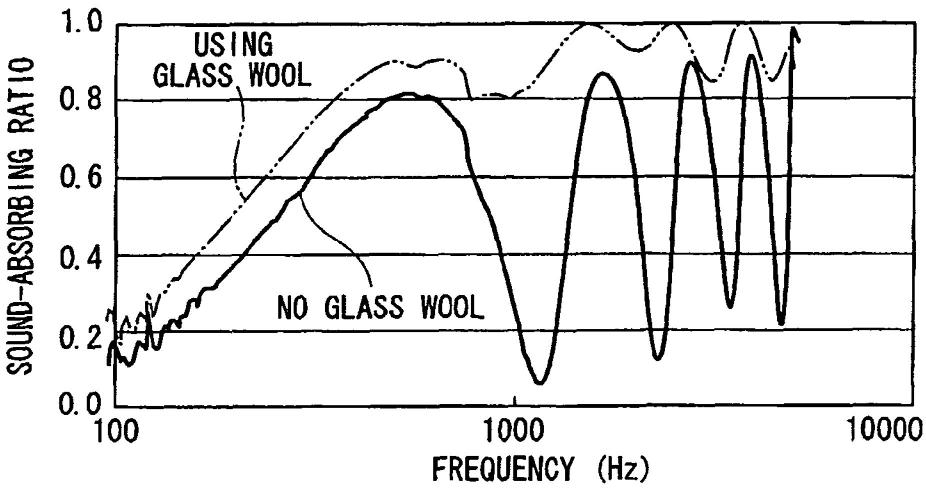

1.0
0.8
0.6
0.4
0.2
0.0
SOUND-ABSORBING RATIO
MEASURED VALUE
CALCULATED VALUE
100
1000
10000
FREQUENCY (Hz)

FIG. 10


1.0
0.8
0.6
0.4
0.2
0.0
SOUND-ABSORBING RATIO
USING GLASS WOOL
NO GLASS WOOL
100
1000
10000
FREQUENCY (Hz)

REFERENCES CITED IN THE DESCRIPTION

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- JP 2005173398 A **[0006]**

Non-patent literature cited in the description

- **DAH-YOU MAA.** Potential of microperforated panel absorber. *J.Acoust.Soc.Am.,* November 1998, vol. 104 (5 **[0043]**