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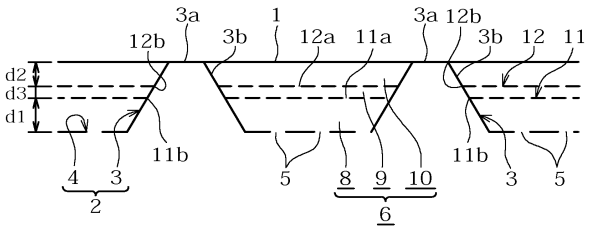
# (54) SOUND ABSORBING STRUCTURE AND METHOD OF PRODUCING THE SAME

(57) A peak frequency having a high sound absorption coefficient is enlarged. A sound absorbing structure body comprises a concave-convex plate (2), a closure plate (1), and first and second partition plates (11) and (12). The concave-convex plate (2) includes a convex portion (3) and a concave portion (4) (concave-convex portion) and an opening (5). The closure plate (1) is bonded to the concave-convex plate (2) so as to form a hollow portion (6) by closing one of the convex portion (3) and the concave portion (4), and the hollow portion (6) is communicated with an outside space through the opening (5). The first and second partition plates (11) and (12) have a number of through holes (11a) and (12a) respectively, and the first and second partition plates (11) and (12) partition the hollow portion (6) into at least two partitioned spaces.

FIG.1




EP 1 662 480 A1

## Description

Technical Field

**[0001]** The present invention relates to a sound absorbing structure body exerting sound insulation performance against sound pressure excitation and a method of producing the sound absorbing structure body. The sound absorbing structure body is suitable for a structural member, a panel, and a sound insulating cover for an automobile, a railroad car, a building, a general purpose machine, and the like.

Background Art

**[0002]** Conventionally, as described in Patent Document 1, there is known a sound absorbing member for a vehicle in which a perforated plate thickness, a hole diameter, a hole pitch, and an air layer thickness are adjusted while a perforated plate is placed on a lower surface side of a panel through an air layer, and thereby noises are absorbed in a predetermined frequency domain. According to the configuration described in Patent Document 1, the noises in a particular frequency can effectively be absorbed by utilizing the Helmholtz Resonance Principle to adjust the perforated plate thickness, the hole diameter, the hole pitch, and the air layer thickness.

**[0003]** Patent Document 1: Japanese Patent Laid-Open No. Hei 6-298014

Disclosure of the Invention

Problems to be Solved by the Invention

**[0004]** However, in the conventional configuration, a sound absorption coefficient is increased only near the Helmholtz resonance frequency, and there is a problem that sound absorbing performance is difficult to broaden.

Means for Solving the Problems

**[0005]** A first invention has a configuration comprising a concave-convex plate which includes a concave-convex portion and an opening; a closure plate which is bonded to the concave-convex plate so as to form a hollow portion by closing one of the concave-convex portion, the hollow portion being communicated with an outside space through the opening; and a first partition member which partitions the hollow portion into at least two first partitioned spaces. According to the configuration of the first invention, the excellent sound absorbing performance in which the frequency band having the high sound absorption coefficient is enlarged can be obtained.

**[0006]** In the concave-convex plate of the first invention, a second invention has a configuration further comprising a closure member which closes the opening of an opened portion in the concave-convex plate, the opened portion whose one end is opened being adjacent to the hollow portion. In the concave-convex plate of the first invention, a third invention has a configuration further comprising a third partition member which partitions an opened portion into at least two third partitioned spaces in the concave-convex plate, the opened portion whose one end is opened being adjacent to the hollow portion. According to the configurations of the second and third inventions, the further high sound absorption coefficient can be obtained.

**[0007]** A fourth invention has a configuration in which the first partition member has a porous plate having a number of through holes. A fifth invention has a configuration in which the third partition member has a porous plate having a number of through holes. According to the configurations of the fourth and fifth inventions, the excellent sound absorbing performance in which the frequency band having the high sound absorption coefficient is enlarged can be obtained. A sixth invention has a configuration in which the first partition member has foil which is provided vibratably or rubbably, and a seventh invention has a configuration in which the third partition member has foil which is provided vibratably or rubbably. In this case, the foil of the sixth invention may have a number of through holes (eighth invention), and the foil of the seventh invention may have a number of through holes (ninth invention). The foil of the sixth invention may have a convex-convex portion (tenth invention), and the foil of the seventh invention may have a convex-convex portion (eleventh invention).

**[0008]** In the first invention, a twelfth invention has a configuration in which a sound absorbing material is provided in at least one of the at-least-two first partitioned spaces. In the third invention, a thirteenth invention has a configuration in which a sound absorbing material is provided in at least one of the at-least-two third partitioned spaces.. According to the configurations of the twelfth and thirteenth inventions, the excellent sound absorbing performance in which the frequency band having the high sound absorption coefficient is enlarged can be obtained.

**[0009]** In the first invention, a fourteenth invention has a configuration in which only one of the at-least-two first partitioned spaces is communicated with the outside space. In the third invention, a fifteenth invention has a configuration in which only one of the at-least-two third partitioned spaces is communicated with the outside space. According to the fourteenth and fifteenth inventions, the configuration is simplified.

**[0010]** A sixteenth invention has a configuration comprising an interior member which includes an opening; an exterior member which is arranged opposite to the interior member while separated from the interior member; a coupling member which couples the interior member and the exterior member to form a hollow portion communicated with an outside space through the opening; and a second partition member which partitions the hollow portion into at least two second partitioned spac-

es. According to the configuration of the sixteenth invention, the excellent sound absorbing performance in which the frequency band having the high sound absorption coefficient is enlarged can be obtained.

**[0011]** A seventeenth invention is characterized in that the interior member is a concave-convex plate having a concave-convex portion, which is integrated with the coupling member and formed by the coupling member, and the exterior member is a closure plate which is bonded so as to close one of the concave-convex portion. According to the configuration of the seventeenth invention, the sound absorbing structure body can easily be produced by integrating the interior member and the coupling member.

**[0012]** In the concave-convex plate of the seventeenth invention, an eighteenth invention has a configuration further comprising a closure member which closes the opening of an opened portion in the concave-convex plate, the opened portion whose one end is opened being adjacent to the hollow portion. In the concave-convex plate of the seventeenth invention, a nineteenth invention has a configuration further comprising a third partition member which partitions an opened portion into at least two third partitioned spaces in the concave-convex plate, the opened portion whose one end is opened being adjacent to the hollow portion. According to the configurations of the eighteenth and nineteenth inventions, the further high sound absorption coefficient can be obtained.

**[0013]** A twentieth invention has a configuration in which the second partition member has a porous plate having a number of through holes. A twenty-first invention has a configuration in which the third partition member has a porous plate having a number of through holes. According to the configurations of the twentieth and twenty-first inventions, the excellent sound absorbing performance in which the frequency band having the high sound absorption coefficient is enlarged can be obtained. A twenty-second invention may have a configuration in which the second partition member has foil which is provided vibratably or rubbably. A twenty-third invention may have a configuration in which the third partition member has foil which is provided vibratably or rubbably. In this case, the foil of the twenty-second invention may have a number of through holes (twenty-fourth invention), and the foil of the twenty-third invention may have a number of through holes (twenty-fifth invention). The foil of the twenty-second invention may have a convex-convex portion (twenty-sixth invention), and the foil of the twenty-third invention may have a convex-convex portion (twenty-seventh invention).

**[0014]** In the sixteenth invention, a twenty-eighth invention has a configuration in which a sound absorbing material is provided in at least one of the at-least-two second partitioned spaces. In the nineteenth invention, a twenty-ninth invention has a configuration in which a sound absorbing material is provided in at least one of the at-least-two third partitioned spaces. According to the configurations of the twenty-eighth and twenty-ninth inventions, the excellent sound absorbing performance in which the frequency band having the high sound absorption coefficient is enlarged can be obtained.

**[0015]** In the sixteenth invention, a thirtieth invention has a configuration in which only one of the at-least-two second partitioned spaces is communicated with the outside space. In the nineteenth invention, a thirty-first invention has a configuration in which only one of the at-least-two third partitioned spaces is communicated with the outside space. According to the thirtieth and thirty-first inventions, the configuration is simplified.

**[0016]** Further, the present invention is a method of producing a sound absorbing structure body comprising a concave-convex plate which includes a concave-convex portion and an opening; a closure plate which is bonded to the concave-convex plate so as to form a hollow portion by closing one of the concave-convex portion, the hollow portion being communicated with an outside space through the opening; and a first partition member which partitions the hollow portion into at least two first partitioned spaces, the sound absorbing structure body producing method wherein a support hole is formed in the first partition member, the support hole is inserted into a convex portion of the concave-convex plate, the support hole is supported and fixed by the convex portion in the midway of the insertion, and thereby the first partition member is provided in the hollow portion. The present invention is a method of producing a sound absorbing structure body comprising a concave-convex plate which includes a concave-convex portion and an opening; a closure plate which is bonded to the concave-convex plate so as to form a hollow portion by closing one of the concave-convex portion, the hollow portion being communicated with an outside space through the opening; and a first partition member which partitions the hollow portion into at least two first partitioned spaces, the sound absorbing structure body producing method wherein a fitting convex portion is formed in the first partition member, the fitting convex portion is fitted into a convex portion of the concave-convex plate, the fitting convex portion is supported and fixed by the convex portion in the midway of the fitting, and thereby the first partition member is provided in the hollow portion.

**[0017]** The present invention is a method of producing a sound absorbing structure body comprising an interior member which includes an opening; an exterior member which is arranged opposite to the interior member while separated from the interior member; a coupling member which couples the interior member and the exterior member to form a hollow portion communicated with an outside space through the opening; and a second partition member which partitions the hollow portion into at least two second partitioned spaces, the interior member being a concave-convex plate having a concave-convex portion, which is integrated with the coupling member and formed by the coupling member, the exterior member being a closure plate which is bonded to close one of the concave-convex portion, the sound absorbing structure

body producing method wherein a support hole is formed in the second partition member, the support hole is inserted into a convex portion of the concave-convex plate, the support hole is supported and fixed by the convex portion in the midway of the insertion, and thereby the second partition member is provided in the hollow portion. The present invention is a method of producing a sound absorbing structure body comprising an interior member which includes an opening; an exterior member which is arranged opposite to the interior member while separated from the interior member; a coupling member which couples the interior member and the exterior member to form a hollow portion communicated with an outside space through the opening; and a second partition member which partitions the hollow portion into at least two second partitioned spaces, the interior member being a concave-convex plate having a concave-convex portion, which is integrated with the coupling member and formed by the coupling member, the exterior member being a closure plate which is bonded to close one of the concave-convex portion, the sound absorbing structure body producing method wherein a fitting convex portion is formed in the second partition member, the fitting convex portion is fitted into a convex portion of the concave-convex plate, the fitting convex portion is supported and fixed by the convex portion in the midway of the fitting, and thereby the second partition member is provided in the hollow portion. Further, the present invention has a configuration in which a number of through holes are formed in the second partition member. Accordingly, the sound absorbing structure body having the partitioned space can easily be produced with high accuracy.

Effect of the Invention

**[0018]** The present invention has an advantage that the frequency band having a high sound absorption coefficient can be enlarged to obtain an excellent sound absorbing performance, since the present invention includes the porous plate which partitions the hollow portion into at least two partitioned spaces.

Best Mode for Carrying Out the Invention

(First Embodiment)

**[0019]** A first embodiment of the present invention will be described below with reference to Figs. 1 to 4.

**[0020]** A sound absorbing structure body according to the first embodiment is preferably used for a sound insulating cover, a structural member, and a panel of a moving apparatus such as an automobile, a railroad car, a construction vehicle, a ship, and an automatic transportation apparatus including a drive mechanism such as an engine therein and an installation machine including a drive mechanism such as a motor and a gear therein, or a floor, a wall, and a ceiling of a building.

**[0021]** As shown in Fig. 1, the sound absorbing structure body has a flat-plate-shaped closure plate 1 and a concave-convex plate 2. The flat-plate-shaped closure plate 1 faces an outside where, for example, noises become problematic, and the concave-convex plate 2 faces a sound source side from which the noise is generated due to the drive mechanism such as the engine. The closure plate 1 and the concave-convex plate 2 are made of metal such as iron and aluminum or of a resin material. It is desirable that the closure plate 1 and the concave-convex plate 2 be made of the same material such that a segregation process is eliminated in recycling.

**[0022]** The concave-convex plate 2 has a flat-plate-shaped concave portion 4 and a plurality of convex portions 3. The convex portion 3 is protruded toward a direction of the closure plate 1 from the concave portion 4, and the convex portion 3 is bonded to the closure plate 1. A number of openings 5 are formed in the concave portion 4. The convex portions 3 are dispersed at predetermined intervals. The convex portion 3 may be continuously provided from one end to the other end. The opening 5 may further be formed in the convex portion 3.

**[0023]** The convex portion 3 is formed in a conical shape while including a flat top portion 3a and a side surface portion 3b. The side surface portion 3b is inclined while a diameter of the side surface portion 3b is enlarged from a circumference of the top portion 3a. The closure plate 1 is bonded to the top portion 3a of the convex portion 3 so as to close the concave portion 4. Therefore, a hollow portion 6 is formed between the closure plate 1 and the concave-convex plate 2. The hollow portion 6 is surrounded by the concave portion 4, the closure plate 1, and the convex portion 3, and the hollow portion 6 is communicated with an outside space through the opening 5.

**[0024]** A first porous plate 11 and a second porous plate 12 (first partition member) are provided in the hollow portion 6. The first and second porous plates 11 and 12 are arranged in parallel with the concave portion 4. The hollow portion 6 is partitioned into three-layer partitioned spaces 8, 9, and 10 sequentially from the sound source side by the first and second porous plates 11 and 12. The porous plates 11 and 12 include a number of through holes 11a and 12a and support holes 11b and 12b respectively. The support holes 11b and 12b are arranged so as to have a positional relationship aligned with an arrangement position of the convex portion 3, and hole diameters of the support holes 11b and 12b are set such that the support holes 11b and 12b are supported by the side surface portion 3b of the convex portion 3. That is, the first porous plate 11 located close to the sound source side differs from the second porous plate 12 located far away from the sound source side in terms of the hole diameter of the support holes 11b and 12b. In other words, the hole diameter of the support hole 11b in the first porous plate 11 is enlarged compared with the hole diameter of the support hole 12b in the second porous plate 12. In the first and second porous plates 11 and 12, the side surface portion 3b of the convex portion 3 abut

onto and support the support holes 11b and 12b having different diameters from each other at different portions on the side surface portion 3b in the midway in which the support holes 11b and 12b are inserted into the convex portion 3. This causes layer thicknesses d1, d2, and d3 of the partitioned spaces 8, 9, and 10 to be set respectively.

**[0025]** A multi-degree-of-freedom vibration system is formed in the state, in which the air in each of the partitioned spaces 8, 9, and 10 acts as a spring and the air in each of the through holes 11a and 12a of the porous plates 11 and 12 acts as a mass. When the sound having a resonance frequency of a resonance system of the multi-degree-of-freedom vibration system is incident from the opening 5, the air in the through holes 11a and 12a in the porous plates 11 and 12 is intensively vibrated to exhibit large sound absorbing power by friction loss.

**[0026]** In at least one member of the through holes 11a and 12a in the first and second porous plates 11 and 12, parameters including a numerical aperture β, a plate thickness t, and a hole diameter b are preferably a combination in which the parameter independently exerts a sound absorption coefficient not lower than 0.3.

**[0027]** It is preferable that the parameters including the layer thickness d, the numerical aperture β, the plate thickness t, and the hole diameter b are set so as to generate a viscous action to the air passing through at least any one of the opening 5 in the concave-convex plate 2 and the through holes 11a and 12a in the first and second porous plates 11 and 12. This is because, when the sound absorbing structure body is formed based on the parameters, the viscous action is generated in the air to create vibration and damping, enabling the sound absorbing characteristics in which a frequency band width whose sound absorption coefficient is not lower than 0.3 becomes not lower than 10% for a resonance frequency f.

**[0028]** That is, in order that the parameters of the sound absorbing structure body have the above sound absorbing characteristics, design conditions are preferably set such that at least one of the concave-convex plate 2 and the porous plates 11 and 12 have the numerical aperture β not more than 3%, each plate thickness t is not lower than 0.3 mm, and the opening 5 and the through holes 11a and 12a have the hole diameters b not more than 0.8 mm.

**[0029]** Although the hole diameters of the opening 5 and the through holes 11a and 12a are not particularly limited, any one of the members has the hole diameter not more than 5 mm, preferably not more than 3 mm, and more preferably not more than 1 mm. The sound absorbing structure body may be formed only by focusing on the hole diameters of the opening 5 and the through holes 11a and 12a. That is, the sound absorbing structure body may be configured to have the first and second porous plates 11 and 12 having a number of through holes 11a and 12a whose diameters are not more than 1 mm. In the case where the hole diameters of the through holes 11a and 12a are set to not more than 1 mm, the viscous action can securely be generated in the air flowing through the through holes 11a and 12a.

**[0030]** It is preferable that a lower limit of the diameters of the opening 5 and the through holes 11a and 12a are 0.2 mm. This is attributed to the fact, although a peak of the sound absorption coefficient theoretically becomes 1.0 when the diameter of the through holes 11a and 12a comes to close to zero, the sound absorption coefficient does not actually reach 1.0, and the viscosity of the air in the through holes 11a and 12a is excessively increased when the diameter becomes as extremely small as a diameter not more than 0.2 mm, so that resistance of the through holes 11a and 12a against the air flow is increased to adversely decrease the sound absorption coefficient. Further, it is attributed to the fact that when the diameter becomes as extremely small as a diameter not more than 0.2 mm, production becomes largely difficult, and the through holes 11a and 12a are easily closed by dirt and dust depending on use environment.

**[0031]** The opening 5 and the through holes 11a and 12a may be formed in an elliptical shape, a rectangular shape, a polygon shape, or a slit shape. Various shapes may be mixed between and inside the opening 5 and the through holes 11a and 12a. Each of the opening 5 and the through holes 11a and 12a may be formed in the same dimension and diameter, or various dimensions and diameters may be mixed between and inside the opening 5 and the through holes 11a and 12a. In case where the various dimensions and diameters are mixed, the frequency band width in which a sufficient sound absorbing performance is exerted can be enlarged.

**[0032]** The sound absorbing structure body of the first embodiment has the configuration in which the partitioned spaces 8, 9, and 10 of layers are arranged in parallel, the present invention is not limited to the first embodiment. That is, the partitioned spaces 8, 9, and 10 of the sound absorbing structure body may be divided or partitioned into arbitrary shapes and volumes in the hollow portion 6 by the partition members which partition the hollow portion 6. For example, the porous plates 11 and 12 may be provided at equal intervals such that the layer thicknesses of the partitioned spaces 8, 9, and 10 become equalized, or the porous plates 11 and 12 may unevenly be provided such that the layer thicknesses become unequal. In this case, the sound absorbing performance can easily be adjusted by changing the partition member.

**[0033]** In the first embodiment, the porous plates 11 and 12 are provided in the hollow portion 6. In addition, as shown in Fig. 11, a porous plate 14 (third partition member) and a porous plate 15 (closure member) may be provided in an opening portion 7, surrounded by the top portion 3a and the side surface portion 3b of the convex portion 3, which is located adjacent to the hollow portion 6. In this case, in order to largely take an air layer, the porous plate 14 and/or the porous plate 15 may have the configuration in which the porous plate 14 and/or the porous plate 15 are/is raised toward the opposite direc-

tion to the convex portion 3. On the contrary, in case where a sound having a high frequency is absorbed, since a thin air layer may be formed, the porous plate 14 and/or the porous plate 15 may have a structure in which the porous plate 14 and/or the porous plate 15 is recessed toward the direction to the convex portion 3. Only the porous plate 15 may be provided while the porous plate 14 is not provided. The porous plates 14 and 15 may be formed by metal foil or a thin film. In this case, the metal foil and the thin film may have the through hole, or the metal foil and thin film may have no through hole.

**[0034]** In the above configuration, a sound absorbing structure body producing method will be described.

**[0035]** First it is actually measured or estimated what kind of frequency characteristics are possessed by noises which are of a sound absorbing target. In order to obtain the sound absorbing characteristics in which the sound absorption coefficient of the frequency band width including a plurality of peak components becomes not lower than 0.3, the parameters are determined in consideration to the air viscosity based on the design conditions, in which the layer thicknesses d1, d2, and d3 are from 1 mm to 50 mm, the numerical apertures $\beta$ of the concave-convex plate 2 and the first and second porous plates 11 and 12 are not more than 15%, the plate thicknesses t are not lower than 0.3 mm, and the hole diameters b of the opening 5 and the through holes 11a and 12a are not more than 0.8 mm.

**[0036]** Then, as shown in Fig. 2, the sound absorbing structure body is produced based on the parameters. Specifically, the metal plate made of iron or aluminum having a predetermined thickness is prepared and set in a press working machine. The metal plate is press-worked to bore the opening 5 while the convex portion 3 is simultaneously formed, which produces the concave-convex plate 2. The metal plates in which the small-diameter through holes 11a and 12a are previously formed are prepared, and the support holes 11b and 12b are respectively formed by the press working similarly to the concave-convex plate 2, which respectively produces the first porous plate 11 and the second porous plate 12. The through holes 11a and 12a may simultaneously be formed along with the support holes 11b and 12b by the press working.

**[0037]** After the concave-convex plate 2 is set on a base, the concave-convex plate 2 is capped with the first porous plate 11 from the upper side of the concave-convex plate 2, and the convex portion 3 is inserted into the support hole 11b. When the side surface portion 3b of the convex portion 3 abut on and support the support hole 11b during the insertion of the convex portion 3 into the support hole 11b, the first porous plate 11 is pressed with a predetermined pressure from the upper side toward the direction of the concave-convex plate 2, which achieves press-contact of the support hole 11b to the convex portion 3 to establish fixation. In order to ensure the fixation, the convex portion 3 and the support hole 11b may be bonded and fixed at an abutting portion by a bonding agent or welding, or the convex portion 3 and the support hole 11b may be coupled with screws. The hollow portion 6 may completely be sealed by the closure plate 1 and the concave-convex plate 2, or the hollow portion 6 may not completely be sealed in case where the closure plate 1 and the top portion 3a are bonded at only one point. That is, the adjacent hollow portions 6 may be communicated with each other through a gap generated between the closure plate 1 and the top portion 3a.

**[0038]** Then, the first porous plate 11 is capped with the second porous plate 12 from the upper side of the first porous plate 11. As with the first porous plate 11, the support hole 12b of the second porous plate 12 is supported and fixed by the convex portion 3 during the insertion into the support hole 12b. Then, the closure plate 1 is placed on the top portion 3a of the convex portion 3 protruded from the support hole 12b of the second porous plate 12, and fixed to the top portion 3a with the bonding agent or the like. Therefore, in the first and second porous plates 11 and 12, while the support holes 11b and 12b having different diameters from each other are fixed to the side surface portion 3b of the convex portion 3 at different portion of the side surface portion 3b, the closure plate 1 is fixed to the top portion 3a of the convex portion 3, which enables the sound absorbing structure body including the partitioned spaces 8, 9, and 10 having the layer thicknesses d1, d2, and d3 to be easily produced with high accuracy.

**[0039]** In case where the porous plates 14 and 15 are provided in the opening portion 7, for example, the porous plates 14 and 15 having different diameters from each other are produced, and the sound absorbing structure body is produced by arranging the porous plates 14 and 15 from the top portion 3a side of the convex portion 3 toward the opening in the order of the porous plate having the smaller diameter.

**[0040]** Then, an operation of the sound absorbing structure body will be described.

**[0041]** When the sound source generates the noise, the noise runs on and reaches the sound absorbing structure body arranged opposing to the sound source. In this case, the sound absorbing structure body is formed with the numerical aperture, the plate thickness of the interior plate, the hole diameter, and the air layer thickness which are all configured to satisfy a required performance. The sound absorbing structure body is configured to include the three-layer partitioned spaces 8, 9, and 10 in which the sound absorbing characteristics exhibit a high sound absorption coefficient in the neighboring bands of a plurality of the resonance frequencies. Accordingly, when the noise reaches the sound absorbing structure body, the noise components of the neighboring bands of a plurality of the resonance frequencies are absorbed by the high sound absorption coefficient, so that the main and wide-frequency-band noises generated by the sound source such as the engine can be absorbed. Therefore, the sound absorbing structure body can absorb the main

and wide-frequency-band noises.

**[0042]** Thus, the sound absorbing structure body of the first embodiment is configured to include the concave-convex plate 2, the closure plate 1, and the first and second porous plates 11 and 12. The concave-convex plate 2 includes the convex portion 3, the concave portion 4 (concave-convex portion), and the opening 5. The closure plate 1 is bonded to the concave-convex plate 2 so as to form the hollow portion 6, communicated with the outside space through the opening 5, by closing one of the convex portion 3 and the concave portion 4. The first and second porous plates 11 and 12 have a number of the through holes 11a and 12a respectively, and the first and second porous plates 11 and 12 partition the hollow portion 6 into at least two partitioned spaces.

**[0043]** Although the present invention is described based on the preferred embodiment, the change could be made without departing from the scope of the present invention.

**[0044]** For example, in the first embodiment, the closure plate 1, the concave portion 4, and the like are formed in a flat plate shape. However, the present invention is not limited to this, but the closure plate 1, the concave portion 4, and the like may locally have a concave and convex plane or a curved plane or partially have a step. In the first embodiment, a case where a plurality of the convex portions 3 are dispersed, while the two porous plates 11 and 12 are provided in the hollow portion 6 formed by the concave portion 4 and the closure plate 1 was explained. However the present invention is not limited to the first embodiment. That is, as shown in Fig. 3, the sound absorbing structure body may be configured to provide at least three porous plates 21 in the hollow portion 6 formed by the concave portion 4 and the closure plate 1 while having the concave-convex plate 2 in which the convex portion 3 is formed so as to surround the circumference of one concave portion 4. In this case, since a number of the partitioned spaces 8, 9, ..., and 10 are formed by the porous plates 21, the number of peak frequencies can further be increased to realize a broader band of the sound absorbing performance. It is obvious that one porous plate 21 may be provided in the hollow portion. The through hole 21a of each porous plate 21 may be formed in various shapes such as an elliptical shape, a rectangular shape, a polygon shape, and a slit shape. The same shape or the same diameter may exist between and inside the porous plates 21 or the various shapes or the various diameters may be mixed between and inside the porous plates 21.

**[0045]** As shown in Fig. 4, the sound absorbing structure body may be formed in the structure in which the configurations of Fig. 3 are arranged in line or arranged in a matrix shape. In this case, the sound absorbing power can be improved. In the opening 5 of the concave-convex plate 2 and the through hole 21a of the porous plate 21, the same shape or the same diameter may exist between and inside the hollow portion 6 or the various shapes or the various diameters may be mixed between and inside the hollow portion 6 arranged in parallel. Therefore, the sound absorbing performance having a wider peak frequency can be obtained. Although the numerical values such as the numerical aperture $\beta$, the layer thickness d, and the plate thickness t are specifically described, the present invention is not limited to them. The numerical values are determined by an environment in which the sound absorbing structure body according to the first embodiment is placed, a required strength and morphology, and the like.

(Second Embodiment)

**[0046]** A second embodiment of the present invention will be described below with reference to Figs. 5 and 6. In the second embodiment, the same component as the first embodiment is designated by the same numeral, and the description will be omitted.

**[0047]** As shown in Fig. 5, a sound absorbing structure body according to the second embodiment has the closure plate 1 and the concave-convex plate 2. The concave-convex plate 2 has the flat-plate-shaped concave portion 4 and a plurality of the convex portions 3. A number of the openings 5 are formed in the concave portion 4. The hollow portion 6 is formed between the closure plate 1 and the concave-convex plate 2. A first porous plate 31 and a second porous plate 32 are provided in the hollow portion 6. The first porous plate 31 and the second porous plate 32 include a number of through holes 31a and 32a and fitting convex portions 31b and 32b.

**[0048]** The fitting convex portions 31b and 32b are arranged so as to have a positional relationship aligned with an arrangement position of the convex portion 3. The fitting convex portions 31b and 32b are set in conical shapes having different depths from each other, and the fitting convex portions 31b and 32b have outer shapes supported by the side surface portion 3b and the top portions 3a of the convex portion 3. That is, the first porous plate 31 located close to the sound source side differs from the second porous plate 32 located far away from the sound source side in the depth. In other words, the depth of the fitting convex portions 31b of the first porous plate 31 is enlarged compared with the depth of the fitting convex portions 32b of the second porous plate 32. In the first and second porous plates 31 and 32, the fitting convex portions 31b and 32b having different depths from each other are fitted into the convex portion 3, and the side surface portion 3b and the top portion 3a of the convex portion 3 abut on and support the fitting convex portions 31b and 32b in the midway of the fitting, which sets the layer thicknesses d1, d2, and d3 of the partitioned spaces 8, 9, and 10 respectively. Similarly to the first embodiment, the porous plates 31 and 32 may be provided at equal intervals such that the layer thicknesses d1, d2, and d3 become equalized, or the porous plates 31 and 32 may unevenly be provided such that the layer thicknesses become unequal. Other configurations are

similar to those of the first embodiment, and the above-described configurations of the first embodiment or the configurations of the modification of the first embodiment may be applied as appropriate.

**[0049]** In the above configuration, a sound absorbing structure body producing method will be described.

**[0050]** As shown in Fig. 6, the sound absorbing structure body is produced by the parameters previously determined by the method of the first embodiment. Specifically, the metal plate made of iron or aluminum is press-worked to bore the opening 5 while the convex portion 3 is simultaneously formed, which produces the concave-convex plate 2. The metal plates in which the small-diameter through holes 31a and 32a are previously formed are prepared, and the fitting convex portions 31b and 32b are respectively formed by the press working similarly to the concave-convex plate 2, which respectively produces the first porous plate 31 and the second porous plate 32. The through holes 31a and 32a may simultaneously be formed along with the fitting convex portions 31b and 32b by the press working.

**[0051]** Then, the concave-convex plate 2 is capped with the first porous plate 31 from the upper side of the concave-convex plate 2, and the convex portion 3 is fitted into the fitting convex portion 31b. When the top portion 3a and side surface portion 3b of the convex portion 3 abut on and support the fitting convex portion 31b, the first porous plate 31 is capped with the second porous plate 32 from the upper side of the first porous plate 31. The fitting convex portion 31b of the first porous plate 31 is fitted into the fitting convex portion 32b of the second porous plate 32, which allows the first porous plate 31 and the second porous plate 32 to be positioned and fixed. The fixation may be performed with the bonding agent. Then, the closure plate 1 is placed on the fitting convex portion 32b of the second porous plate 32, and the closure plate 1 is bonded to the fitting convex portion 32b with the bonding agent or the like. Therefore, in the first and second porous plates 31 and 32, while the fitting convex portion 31b and 32b having different dimensions (depths) from each other are fixed at the convex portion 3, the closure plate 1 is fixed to the top portion of the fitting convex portion 32b, which enables the sound absorbing structure body including the partitioned spaces 8, 9, and 10 having the layer thicknesses d1, d2, and d3 to be easily produced with high accuracy. Other producing methods are similar to those of the first embodiment.

**[0052]** According to the sound absorbing structure body which is produced and configured in the above-described manner, the noise components of the neighboring bands of a plurality of the resonance frequencies are absorbed by the high sound absorption coefficient, so that the main and wide-frequency-band noises generated by the sound source such as the engine can be absorbed.

(Third Embodiment)

**[0053]** A third embodiment of the present invention will be described below with reference to Fig. 7. In the third embodiment, the same component as the first embodiment is designated by the same numeral, and the description will be omitted.

**[0054]** As shown in Fig. 7, in a sound absorbing structure body according to the third embodiment, a plurality of porous plates 41 are provided in the hollow portion 6 which is formed by the concave-convex plate 2 and the opening 5 bonded to the concave-convex plate 2. In the concave-convex plate 2, a number of openings 5 are provided in the convex portion 3 and the concave portion 4. Similarly to the first embodiment, the porous plate 41 has a number of through holes 41a, and the porous plate 41 has the support holes 41b set at the hole diameters according to the layers respectively. A plurality of the porous plates 41 may be provided at equal intervals, or the porous plates 41 may be provided at uneven intervals. A thin-film sound absorbing body 44 is provided in the hollow portion 6. The thin-film sound absorbing body 44 may be provided among a plurality of the porous plates 41. The thin-film sound absorbing body 44 may be provided between the porous plate 41 and the concave-convex plate 2 or between the porous plate 41 and the closure plate 1, and it is desirable that the thin-film sound absorbing body 44 be provided in the optimum arrangement state according to the sound source which is of the sound absorbing target.

**[0055]** The thin-film sound absorbing body 44 includes two thin films 42 and 43. In the thin films 42 and 43, surfaces are formed in a plane. The surfaces of the thin films 42 and 43 are slightly separated from each other, and the surfaces are adjacent to each other while being able to come into contact with each other during the vibration. Although a metal thin film formed by aluminum foil, a thin film made of a resin such as vinyl chloride, and the like can be used as the thin films 42 and 43, the thin films 42 and 43 are not limited to the above thin films. Other configurations are similar to those of the first embodiment, and the above-described configurations of the first embodiment or the configurations of the modification of the first embodiment may be applied as appropriate.

**[0056]** Thus, in the sound absorbing structure body of the third embodiment, at least one thin-film sound absorbing body 44 (foil) is provided in at least one of partitioned spaces into which the hollow portion 6 is partitioned while the thin-film sound absorbing body 44 can vibrate or rub against each other. According to the configuration of the third embodiment, in the sound absorbing structure body, in addition to an operation in which the same sound absorbing performance as the first embodiment is exerted, the two thin films 42 and 43 vibrate by incidence of an acoustic wave, and the thin films 42 and 43 come into contact with each other to rub against each other with the vibration, which allows acoustic energy to be lost. Therefore, compared with the configura-

tion in which the energy is dissipated by the resonance phenomenon, an excellent sound absorbing performance can be exerted in a broad band. Since the thin-film sound absorbing body 44 made of the metal such as aluminum foil or the resin such as vinyl chloride can be used as the sound absorbing structure body, the thin-film sound absorbing body 44 is easily recycled compared with a difficult-to-recycle material such as glass-wool which is conventionally to be disposed of as shredder dust and the like.

**[0057]** The thin films 42 and 43 may have a number of minute convex portions, and the thin films may be laminated such that the thin films come into contact with each other by the convex portions. In this case, when the acoustic wave is incident, the thin films 42 and 43 vibrate and the overlapped portions come into contact with each other to rub against each other, so that the acoustic wave energy can be dissipated to realize the sound absorption.

**[0058]** In the thin films 42 and 43 of the thin-film sound absorbing body 44, the fine through holes are formed in the thickness direction, and the through holes in the thin films 42 and 43 may be overlapped each other or not overlapped each other when viewed in the laminated direction. In the case where the through holes are overlapped, not only the thin films 42 and 43 vibrate and rub against each other to achieve an excellent sound deadening effect in a broad band, but also the more excellent sound deadening effect can be exerted since the acoustic wave is further damped when the acoustic wave passes through the through hole.

**[0059]** In case where a through hole of one of the thin films 42 and 43 is formed at the position where the through hole is not overlapped with the through hole of the other thin film, the acoustic wave passes through the through hole of the thin film 43 from the incident side, runs between the two thin films 42 and 43, and passes through the through hole of the thin film 42. Accordingly, since the acoustic wave propagates along inner surfaces of the two thin films 42 and 43, the sound deadening effect is further exerted by both a damping action in the passage of the acoustic wave through the through hole and a viscous damping action in the propagation of the acoustic wave on the surface of the thin films 42 and 43. In the thin-film sound absorbing body 44, a further excellent damping effect is obtained by forming a fine through hole, which remarkably improves the sound deadening effect. The through hole may not be formed in the thin-film sound absorbing body 44.

**[0060]** Instead of the convex portion, the thin-film sound absorbing body 44 may be folded so as to have regions overlapped with each other while being in contact with each other. In this case, when the overlapped regions come into contact with each other to rub against each other, the acoustic wave energy can be dissipated, which allows the high sound absorption coefficient to be realized in the broad band. Even if two thin films 42 and 43 are decreased to one, the sound absorbing structure can be achieved in the overlapped portion, so that cost can be reduced.

**[0061]** In the third embodiment, the porous plate 41 and the thin-film sound absorbing body 44 are provided in the sound absorbing structure body. However, since the thin-film sound absorbing body 44 has the sound absorbing effect in itself, only the thin-film sound absorbing body 44 may be provided in the sound absorbing structure body. Similarly to the first embodiment, as shown in Fig. 12, a thin-film sound absorbing body 45 may be provided in the opening portion 7 surrounded by the top portion 3a and side surface portion 3b of the convex portion 3. In this case, the thin-film sound absorbing body 45 may be a porous plate similar to the porous plate 41, or both the thin-film sound absorbing body 45 and the porous plate may be provided.

(Fourth Embodiment)

**[0062]** A fourth embodiment of the present invention will be described below with reference to Fig. 8. In the fourth embodiment, the same component as the first and third embodiments is designated by the same numeral, and the description will be omitted.

**[0063]** As shown in Fig. 8, in a sound absorbing structure body according to the fourth embodiment, a plurality of the porous plates 41 are provided in the hollow portion 6 which is formed by the concave-convex plate 2 and the opening 5 bonded to the concave-convex plate 2. In the concave-convex plate 2, a number of the openings 5 are provided in the convex portion 3 and the concave portion 4. Similarly to the third embodiment, a plurality of the porous plates 41 may be provided at equal intervals, or the porous plates 41 may be provided at uneven intervals. A sound absorbing material 51 is provided in the hollow portion 6. The sound absorbing material 51 is provided in an arbitrary region (partitioned space) of the hollow portion 6. For example, the sound absorbing material 51 is provided in the whole portion or a part of the portion between the porous plate 41 and the closure plate 1, between the porous plates 41 and 41, or between the porous plate 41 and the concave-convex plate 2. The region where the sound absorbing material 51 is provided may be located at the same position or at different position in each hollow portion 6.

**[0064]** The sound absorbing material 51 is made of a porous material. The porous material may be formed by compressing metal fiber or strip metal such as aluminum, stainless, glass-wool, and PET fiber. The porous material may be made of non-woven fabric, or made of metal or resin foaming material. In the porous material, when the closure plate 1 and the concave-convex plate 2 are made of metal, it is desirable that the porous material be made of the same metal such that a good recycling property is obtained. Other configurations are similar to those of the first and third embodiments, and the above-described configurations of the first and third embodiments or the configurations of the modification of the first and third embodiments may be applied as appropriate.

**[0065]** According to the configuration of the fourth embodiment, in the sound absorbing structure body, the sound absorbing material 51 can absorb the noises of the band wider than the frequency band which can sufficiently be absorbed by the Helmholtz Resonance Principle, so that the sound absorbing structure body can further improve the sound insulating performance.

**[0066]** In the fourth embodiment, only the sound absorbing material 51 is provided in the hollow portion 6. However, the present invention is not limited to the fourth embodiment, but the sound absorbing material 51 may be provided along with the thin-film sound absorbing body 44 of the third embodiment. The sound absorbing structure body may have the configuration in which the sound absorbing material 51 is provided around the concave-convex plate 2. Similarly to the first embodiment, as shown in Fig. 13, a sound absorbing material 52 may be provided in the opening portion 7 surrounded by the top portion 3a and side surface portion 3b of the convex portion 3.

(Fifth Embodiment)

**[0067]** A fifth embodiment of the present invention will be described below with reference to Fig. 14. In the fifth embodiment, the same component as the first to fourth embodiments is designated by the same numeral, and the description will be omitted.

**[0068]** As shown in Fig. 14, a sound absorbing structure body according to the fifth embodiment includes a flat-plate-shaped interior plate 2a (interior member), the closure plate 1 (exterior member), and a coupling member 13. The interior plate 2a has a number of the openings 5. The closure plate 1 is arranged opposite to the interior plate 2a while separated from the interior plate 2a. The coupling member 13 couples the interior plate 2a and the closure plate 1 to form the hollow portion 6. The closure plate 1 and the interior plate 2a are plate members made of metal such as iron and aluminum, the resin material, or the foil. The coupling member 13 includes a flat top portion 13a and a side surface portion 13b provided in the circumference of the top portion 13a, and the coupling member 13 is formed in a columnar shape. That is, the coupling member 13 has the same configuration as the convex portion 3 of the first embodiment. The interior plate 2a and the closure plate 1 are coupled to each other such that the top portion 13a is bonded to the closure plate 1, which forms the hollow portion 6 between the coupling members 13. The coupling member 13 may be formed in the shape with no top portion 13a, i.e., in a cylindrical shape having only the side surface portion 13b.

**[0069]** The hollow portion 6 is communicated with the outside space through the opening 5. A first parous plate 61 and a second porous plate 62 (second partition member) are provided in the hollow portion 6. The first and second porous plates 61 and 62 include a number of through holes 61a and 62a. The first and second porous plates 61 and 62 are arranged in parallel with the interior plate 2a, and the first and second porous plates 61 and 62 partition the hollow portion 6 into the three-layer partitioned spaces 8, 9, and 10 in the order from the sound source side. The porous plates 61 and 62 may be provided at equal intervals such that the layer thicknesses of the partitioned spaces 8, 9, and 10 become equalized, or the porous plates 61 and 62 may unevenly be provided such that the layer thicknesses become unequal. The action of the sound absorbing structure body of the fifth embodiment is similar to that of the first embodiment, so that the description will be omitted.

**[0070]** Thus, the sound absorbing structure body of the fifth embodiment is configured to include the interior plate 2a (interior member), the closure plate 1 (exterior member), the coupling member 13, and the first and second porous plates 61 and 62 (second partition member). The interior plate 2a includes the openings 5. The closure plate 1 is arranged opposite to the interior plate 2a while separated from the interior plate 2a. The coupling member 13 couples the interior plate 2a and the closure plate 1 to form the hollow portion 6 communicated with the outside through the opening 5. The first and second porous plates 61 and 62 partitions the hollow portion 6 into at least two partitioned spaces. According to the configuration of the fifth embodiment, similarly to the first embodiment, the effect that an excellent sound absorbing performance in which the frequency band having the high sound absorption coefficient is enlarged can be obtained. The coupling member 13 and the interior plate 2a can be formed with different members by individually forming the coupling member 13 and the interior plate 2a.

**[0071]** Although the coupling member 13 of the fifth embodiment is formed in a columnar shape, the coupling member 13 may be formed in other shapes. The coupling member 13 may be formed in any shape as long as the closure plate 1 and the interior plate 2a are coupled to form the hollow portion 6. For example, the coupling member 13 may be formed in a conical shape or a cylindrical shape whose cross section has polygon. The coupling member 13 shown in Fig. 14 may be formed in a plate shape. In the case where the coupling member 13 is formed in the plate shape, as shown in Fig. 15, the first and second porous plates 61 and 62 may be provided between the coupling members 13 and 13. In this case, a higher sound absorption coefficient can be obtained. At least two porous plates may be provided. In this case, since a number of the partitioned spaces 8, 9, ..., and 10 are formed by the porous plate 21, the number of p peak frequencies can further be increased to realize a broad band of the sound absorbing performance. Although the porous plates 61 and 62 are provided in the hollow portion 6, the porous plates may be provided in the opening portion surrounded by the top portion 13a and side surface portion 13b of the coupling member 13 adjacent to the hollow portion 6. Although the closure plate 1 and the interior plate 2a are formed in a flat plate shape, the closure plate 1 and the interior plate 2a may locally have a

concave-convex surface or a curved surface, or the closure plate 1 and the interior plate 2a may partially have a step.

**[0072]** The interior plate 2a and the coupling member 13 may be integrated with each other to form one member. That is, the interior plate 2a is integrated with the coupling member 13, the interior plate 2a is a concave-convex plate, formed by the coupling member 13, having the concave-convex portion, and the closure plate 1 may have the configuration in which the closure plate 1 is bonded so as to close one of the concave-convex portion. In this case, since the interior plate 2a and the coupling member 13 can be produced at once, the sound absorbing structure body can easily be produced. In this case, an opening having the same width as the opening portion of the coupling member 13 may be provided in the interior plate 2a such that the opening portion surrounded by the top portion 13a and side surface portion 13b of the coupling member 13 is opened. The coupling member 13 may be formed by folding the closure plate 1, the interior plate 2a, the porous plates 61 and 62, or the like. A plurality of the through holes may be provided in the coupling member 13. In this case, the resonance generated in the direction parallel to the closure plate 1 and the interior plate 2a can be prevented. The damping effect can also be improved when the acoustic wave passes through the through hole.

**[0073]** As described in the fourth embodiment, the sound absorbing members 51 and 52 may be arranged in any one of the partitioned spaces 8, 9, 10 of the hollow portion 6. The first and second porous plates 61 and 62 may be formed by the metal foil, the thin films 42 and 43 described in the third embodiment, or the like. In this case, the metal foil and the thin film may have a through hole or may not have the through hole. The above-described configurations of the first to fourth embodiments or the configurations of the modification of the first to fourth embodiments may be applied as appropriate.

**[0074]** In the configuration of the fifth embodiment, a sound absorbing structure body producing method will be described. The producing method described below is the sound absorbing structure body producing method, in which the interior plate 2a and the coupling member 13 are integrated and the coupling member 13 forms concave-convex portion.

**[0075]** First, similarly to the production method of the first embodiment, the parameters (layer thicknesses of partitioned spaces 8, 9, and 10, hole diameter of opening 5, and the like) are determined. Then, as shown in Fig. 16, the sound absorbing structure body is produced based on the determined parameters. Specifically, the metal plate made of iron, aluminum or the like having the predetermined thickness is prepared, and the metal plate is set in the press working machine. Then, the metal plate is press-worked to bore the opening 5 while the convex portion 13 (top portion 13a and side surface portion 13b) is simultaneously formed, which produces the interior plate 2a. The metal plates in which the small-diameter through holes 61a and 62a are previously formed are prepared, and support holes 61b and 62b are respectively formed by the press working similarly to the interior plate 2a, which respectively produces the first porous plate 61 and the second porous plate 62.

**[0076]** As shown in Fig. 16, the coupling member 13 and the support holes 61b and 62b are formed so as to be lengthened in one direction. The coupling member 13 is formed in a shape in which the diameter is gradually decreased toward the direction in which the coupling member 13 moves away from the metal plate. The coupling member 13 can be inserted into the support holes 61b and 62b, and the support holes 61b and 62b have the diameters with which the side surface portion 13b of the coupling member 13 is engaged during the insertion. The through holes 61a and 62a may simultaneously be formed along with the support holes 61b and 62b by the press working.

**[0077]** After the interior plate 2a is set on the base, the interior plate 2a is capped with the first porous plate 61 from the upper side of the interior plate 2a, and the coupling member 13 is inserted into the support hole 61b. When the side surface portion 13b of the coupling member 13 abuts on and support the support hole 61b during the insertion, the first porous plate 61 is pressed with a predetermined pressure from the upper side in the direction of the interior plate 2a, which achieves the press-contact of the support hole 61b to the coupling member 13 to establish the fixation. In order to ensure the fixation, the coupling member 13 and the support hole 61b may be bonded at the abutting portion by the bonding agent or the welding, or the coupling member 13 and the support hole 61b may be coupled with the screws. The hollow portion 6 may completely be sealed by the closure plate 1 and the interior plate 2a, or the hollow portion 6 may not completely be sealed in case where the closure plate 1 and the top portion 13a are bonded at only one point. That is, the adjacent hollow portions 6 may be communicated with each other through the gap generated between the closure plate 1 and the top portion 13a.

**[0078]** Then, the first porous plate 61 is capped with the second porous plate 62 from the upper side of the first porous plate 61. As with the first porous plate 61, the support hole 62b of the second porous plate 62 is supported and fixed by the coupling member 13 during the insertion. Then, the closure plate 1 is placed on the top portion 13a of the coupling member 13 protruded from the support hole 62b of the second porous plate 62, and the closure plate 1 is bonded and fixed to the top portion 13a with the bonding agent or the like. Therefore, in the first and second porous plates 61 and 62, while the support holes 61b and 62b having different diameters from each other are fixed to the side surface portion 13b of the coupling member 13 at a different portion of the side surface portion 3b, the closure plate 1 is fixed to the top portion 13a of the coupling member 13, which enables the sound absorbing structure body including the partitioned spaces 8, 9, and 10 having the layer thicknesses

to be easily produced with high accuracy.

**[0079]** Thus, the method of producing the sound absorbing structure body of the fifth embodiment is the method of producing the sound absorbing structure body including the interior plate 2a (interior member) which includes the openings 5; the closure plate 1 (exterior member) which is arranged opposite to the interior plate 2a while separated from the interior plate 2a; the coupling member 13 which couples the interior plate 2a and the closure plate 1 to form the hollow portion communicated with the outside space through the opening 5; and the porous plates 61 and 62 (second partition member) which partition the hollow portion 6 into at least two second partitioned spaces, the interior plate 2a being the concave-convex plate having the concave-convex portion, which is integrated with the coupling member 13 and formed by the coupling member 13, the closure plate 1 being the closure plate which is bonded to close one of the concave-convex portion, the support holes 61b and 62b are formed in the porous plates 61 and 62, the support holes 61b and 62b are inserted into the convex portion of the concave-convex plate, the support hole is supported and fixed by the convex portion in the midway of the insertion, and thereby the porous plates 61 and 62 are provided in the hollow portion 6.

**[0080]** As shown in Fig. 17, similarly to the producing method in the second embodiment, fitting convex portions 61c and 62c may be formed in the first porous plate 61 and the second porous plate 62 as a modification of the producing method of the fifth embodiment. Specifically, the metal plate made of iron or aluminum is press-worked to bore the opening 5 while the coupling member 13 is simultaneously formed, which produces the interior plate 2a. The coupling member 13 is formed in a flat plate shape from one end of the metal plate to the other end. The metal plates in which the small-diameter through holes 61a and 62a are previously formed are prepared, and the fitting convex portions 61c and 62c are respectively formed by the press working similarly to the interior plate 2a, which respectively produces the first porous plate 61 and the second porous plate 62. The fitting convex portion 61c has the dimension in which the coupling member 13 can be fitted into the fitting convex portion 61c, and the coupling member 13 and fitting convex portion 61c can be fitted into the fitting convex portion 62c. The through holes 61a and 62a may simultaneously be formed along with the fitting convex portions 61b and 62b by the press working.

**[0081]** Then, the interior plate 2a is capped with the first porous plate 61 from the upper side of the interior plate 2a, and the coupling member 13 is fitted into the fitting convex portion 61c. When the top portion 13a and side surface portion 13b of the coupling member 13 abut on and support the fitting convex portion 61c, the first porous plate 61 is capped with the second porous plate 62 from the upper side of the first porous plate 61. The fitting convex portion 61c of the first porous plate 61 is fitted into the fitting convex portion 62c of the second porous plate 62, which allows the first porous plate 61 and the second porous plate 62 to be positioned and fixed. The fixation may be performed with the bonding agent. Then, the closure plate 1 is placed on the fitting convex portion 62c of the second porous plate 62, and the closure plate 1 is bonded and fixed to the fitting convex portion 62c with the bonding agent or the like. Therefore, in the first and second porous plates 61 and 62, while the fitting convex portion 61c and 62c having different dimensions (depths) from each other are fixed at the coupling member 13, the closure plate 1 is fixed to the top portion of the fitting convex portion 62c, which enables the sound absorbing structure body including the partitioned spaces 8, 9, and 10 having the layer thicknesses to be easily produced with high accuracy. In case where the coupling member 13 is fixed by the fitting convex portions 61c and 62c, unlike the case where the coupling member 13 is fixed by the support holes 61b and 62b, the coupling member 13 can be formed in a flat plate shape, and the sound absorbing structure body can be formed according to the circumstances.

**[0082]** Thus, another method of producing the sound absorbing structure body of the fifth embodiment is the method of producing the sound absorbing structure body including the interior plate 2a (interior member) which includes the openings 5; the closure plate 1 (exterior member) which is arranged opposite to the interior plate 2a while separated from the interior plate 2a; the coupling member 13 which couples the interior plate 2a and the closure plate 1 to form the hollow portion communicated with the outside space through the opening 5; and the porous plates 61 and 62 (second partition member) which partition the hollow portion 6 into at least two second partitioned spaces, the interior plate 2a being the concave-convex plate having the concave-convex portion, which is integrated with the coupling member 13 and formed by the coupling member 13, the closure plate 1 being the closure plate which is bonded to close one of the concave-convex portion, the fitting convex portions 61c and 62c are formed in the porous plates 61 and 62, the fitting convex portions 61c and 62c are fitted into the convex portion of the concave-convex plate, the fitting convex portions 61c and 62c are supported and fixed by the convex portion in the midway of the fitting, and thereby the porous plates 61 and 62 are provided in the hollow portion 6.

Example 1

**[0083]** The sound absorbing characteristics were simulated for the sound absorbing structure body of the first embodiment. Specifically, as shown in Fig. 1, the parameters were set as follows. The layer thicknesses d1 and d2 of the partitioned spaces 8 and 9 were 8 mm and 8 mm, the numerical apertures $\beta$ of the through holes 11a and 12a of the porous plates 11 and 12 were 1% respectively, the plate thicknesses t of the porous plates 11 and 12 were 0.3 mm, the hole diameters of the through holes

11a and 12a were 0.5 mm, the numerical aperture β of the opening 5 was 7.3%, the plate thickness t of the opening 5 was 0.7 mm, and the hole diameter of the opening 5 was 2 mm. In this case, as shown in Fig. 9, in addition to the resonance frequency around 1800 Hz, the sound absorbing structure body has the resonance frequency around 4050 Hz. Compared with the case where the porous plate is not provided, the sound absorbing structure body of the first embodiment has a high sound absorption coefficient in a wide range around a plurality of the frequencies.

Example 2

**[0084]** The sound absorbing characteristics were simulated for a sound absorbing structure body approximate to the third embodiment. Specifically, the parameters were set at the same conditions as the first embodiment. In case where double aluminum foil films are used as the thin films 42 and 43 of the thin-film sound absorbing body 44, as shown in Fig. 10, a high sound absorption coefficient is obtained in the range from the resonance frequency around 1950 Hz to the resonance frequency around 3200 Hz. Compared with the case where the porous plate is not provided, the sound absorbing structure body has a high sound absorption coefficient in a remarkably wide range.

Brief Description of the Drawings

**[0085]**

Fig. 1 is a schematic diagram of a sound absorbing structure body;
Fig. 2 is an exploded perspective view of a sound absorbing structure body;
Fig. 3 is a schematic diagram of a sound absorbing structure body;
Fig. 4 is a schematic diagram of a sound absorbing structure body;
Fig. 5 is a schematic diagram of a sound absorbing structure body;
Fig. 6 is an exploded perspective view of a sound absorbing structure body;
Fig. 7 is a schematic diagram of a sound absorbing structure body;
Fig. 8 is a schematic diagram of a sound absorbing structure body;
Fig. 9 is a graph showing sound absorbing characteristics;
Fig. 10 is a graph showing sound absorbing characteristics;
Fig. 11 is a schematic diagram of a sound absorbing structure body of a modification;
Fig. 12 is a schematic diagram of a sound absorbing structure body of a modification;
Fig. 13 is a schematic diagram of a sound absorbing structure body of a modification;
Fig. 14 is a schematic diagram of a sound absorbing structure body;
Fig. 15 is a schematic diagram of a sound absorbing structure body of a modification;
Fig. 16 is an exploded perspective view of a sound absorbing structure body; and
Fig. 17 is an exploded perspective view of a sound absorbing structure body.

Explanation of the Reference Numerals

**[0086]**

| | |
|---|---|
| 1 | closure plate |
| 2 | concave-convex plate |
| 3 | convex portion |
| 4 | concave portion |
| 5 | opening |
| 6 | hollow portion |
| 11 | first porous plate |
| 12 | second porous plate |
| 21 | porous plate |
| 31 | first porous plate |
| 41 | porous plate |
| 51 | sound absorbing material |

**Claims**

**1.** A sound absorbing structure body comprising:

a concave-convex plate which includes a concave-convex portion and an opening;
a closure plate which is bonded to said concave-convex plate so as to form a hollow portion by closing one of said concave-convex portion, the hollow portion being communicated with an outside space through said opening; and
a first partition member which partitions said hollow portion into at least two first partitioned spaces.

**2.** The sound absorbing structure body according to claim 1, further comprising a closure member which closes said opening of an opened portion in said concave-convex plate, the opened portion whose one end is opened being adjacent to said hollow portion.

**3.** The sound absorbing structure body according to claim 1, further comprising a third partition member which partitions an opened portion into at least two third partitioned spaces in said concave-convex plate, the opened portion whose one end is opened being adjacent to said hollow portion.

**4.** The sound absorbing structure body according to claim 1, wherein said first partition member has a porous plate having a number of through holes.

**5.** The sound absorbing structure body according to claim 3, wherein said third partition member has a porous plate having a number of through holes.

**6.** The sound absorbing structure body according to claim 1, wherein said first partition member has foil which is provided vibratably or rubbably.

**7.** The sound absorbing structure body according to claim 3, wherein said third partition member has foil which is provided vibratably or rubbably.

**8.** The sound absorbing structure body according to claim 6, wherein said foil has a number of through holes.

**9.** The sound absorbing structure body according to claim 7, wherein said foil has a number of through holes.

**10.** The sound absorbing structure body according to claim 6, wherein said foil has a convex-convex portion.

**11.** The sound absorbing structure body according to claim 7, wherein said foil has a convex-convex portion.

**12.** The sound absorbing structure body according to claim 1, wherein a sound absorbing material is provided in at least one of said at-least-two first partitioned spaces.

**13.** The sound absorbing structure body according to claim 3, wherein a sound absorbing material is provided in at least one of said at-least-two third partitioned spaces.

**14.** The sound absorbing structure body according to claim 1, wherein only one of said at-least-two first partitioned spaces is communicated with said outside space.

**15.** The sound absorbing structure body according to claim 3, wherein only one of said at-least-two third partitioned spaces is communicated with said outside space.

**16.** A sound absorbing structure body comprising:

an interior member which includes an opening;
an exterior member which is arranged opposite to said interior member while separated from said interior member;
a coupling member which couples said interior member and said exterior member to form a hollow portion communicated with an outside space through said opening; and
a second partition member which partitions said hollow portion into at least two second partitioned spaces.

**17.** A sound absorbing structure body according to claim 16, wherein said interior member is a concave-convex plate having a concave-convex portion, which is integrated with said coupling member and formed by the coupling member, and
said exterior member is a closure plate which is bonded so as to close one of said concave-convex portion.

**18.** The sound absorbing structure body according to claim 17, further comprising a closure member which closes said opening of an opened portion in said concave-convex plate, the opened portion whose one end is opened being adjacent to said hollow portion.

**19.** The sound absorbing structure body according to claim 17, further comprising a third partition member which partitions an opened portion into at least two third partitioned spaces in said concave-convex plate, the opened portion whose one end is opened being adjacent to said hollow portion.

**20.** The sound absorbing structure body according to claim 16, wherein said second partition member has a porous plate having a number of through holes.

**21.** The sound absorbing structure body according to claim 19, wherein said third partition member has a porous plate having a number of through holes.

**22.** The sound absorbing structure body according to claim 16, wherein said second partition member has foil which is provided vibratably or rubbably.

**23.** The sound absorbing structure body according to claim 19, wherein said third partition member has foil which is provided vibratably or rubbably.

**24.** The sound absorbing structure body according to claim 22, wherein said foil has a number of through holes.

**25.** The sound absorbing structure body according to claim 23, wherein said foil has a number of through holes.

**26.** The sound absorbing structure body according to claim 22, wherein said foil has a concave- convex portion.

**27.** The sound absorbing structure body according to claim 23, wherein said foil has a concave- convex portion.

**28.** The sound absorbing structure body according to claim 16, wherein a sound absorbing material is provided in at least one of said at-least-two second partitioned spaces.

**29.** The sound absorbing structure body according to claim 19, wherein a sound absorbing material is provided in at least one of said at-least-two third partitioned spaces.

**30.** The sound absorbing structure body according to claim 16, wherein only one of said at-least-two second partitioned spaces is communicated with said outside space.

**31.** The sound absorbing structure body according to claim 19, wherein only one of said at-least-two third partitioned spaces is communicated with said outside space.

**32.** A method of producing a sound absorbing structure body comprising a concave-convex plate which includes a concave-convex portion and an opening; a closure plate which is bonded to said concave-convex plate so as to form a hollow portion by closing one of said concave-convex portion, the hollow portion being communicated with an outside space through said opening; and a first partition member which partitions said hollow portion into at least two first partitioned spaces,
the sound absorbing structure body producing method wherein a support hole is formed in said first partition member, the support hole is inserted into a convex portion of said concave-convex plate, said support hole is supported and fixed by said convex portion in the midway of the insertion, and thereby said first partition member is provided in said hollow portion.

**33.** The sound absorbing structure body producing method according to claim 32, wherein a number of through holes are formed in said first partition member.

**34.** A method of producing a sound absorbing structure body comprising a concave-convex plate which includes a concave-convex portion and an opening; a closure plate which is bonded to said concave-convex plate so as to form a hollow portion by closing one of said concave-convex portion, the hollow portion being communicated with an outside space through said opening; and a first partition member which partitions said hollow portion into at least two first partitioned spaces,
the sound absorbing structure body producing method wherein a fitting convex portion is formed in said first partition member, the fitting convex portion is fitted into a convex portion of said concave-convex plate, said fitting convex portion is supported and fixed by said convex portion in the midway of the fitting, and thereby said first partition member is provided in said hollow portion.

**35.** The sound absorbing structure body producing method according to claim 34, wherein a number of through holes are formed in said first partition member.

**36.** A method of producing a sound absorbing structure body comprising an interior member which includes an opening; an exterior member which is arranged opposite to said interior member while separated from said interior member; a coupling member which couples said interior member and said exterior member to form a hollow portion communicated with an outside space through said opening; and a second partition member which partitions said hollow portion into at least two second partitioned spaces, said interior member being a concave-convex plate having a concave-convex portion, which is integrated with said coupling member and formed by the coupling member, said exterior member being a closure plate which is bonded to close one of said concave-convex portion,
the sound absorbing structure body producing method wherein a support hole is formed in said second partition member, the support hole is inserted into a convex portion of said concave-convex plate, said support hole is supported and fixed by said convex portion in the midway of the insertion, and thereby said second partition member is provided in said hollow portion.

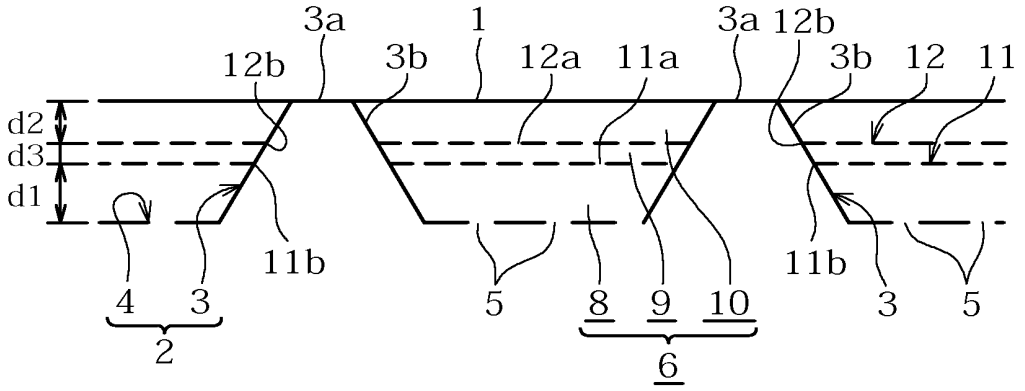
**37.** The sound absorbing structure body producing method according to claim 36, wherein a number of through holes are formed in said second partition member.

**38.** A method of producing a sound absorbing structure body comprising an interior member which includes an opening; an exterior member which is arranged opposite to said interior member while separated from said interior member; a coupling member which couples said interior member and said exterior member to form a hollow portion communicated with an outside space through said opening; and a second partition member which partitions said hollow portion into at least two second partitioned spaces, said interior member being a concave-convex plate having a concave-convex portion, which is integrated with said coupling member and formed by the coupling member, said exterior member being a closure plate which is bonded to close one of said concave-convex portion,
the sound absorbing structure body producing method wherein a fitting convex portion is formed in said

second partition member, the fitting convex portion is fitted into a convex portion of said concave-convex plate, said fitting convex portion is supported and fixed by said convex portion in the midway of the fitting, and thereby said second partition member is provided in said hollow portion.

**39.** The sound absorbing structure body producing method according to claim 38, wherein a number of through holes are formed in said second partition member.

FIG.1




SOUND SOURCE SIDE

FIG.2

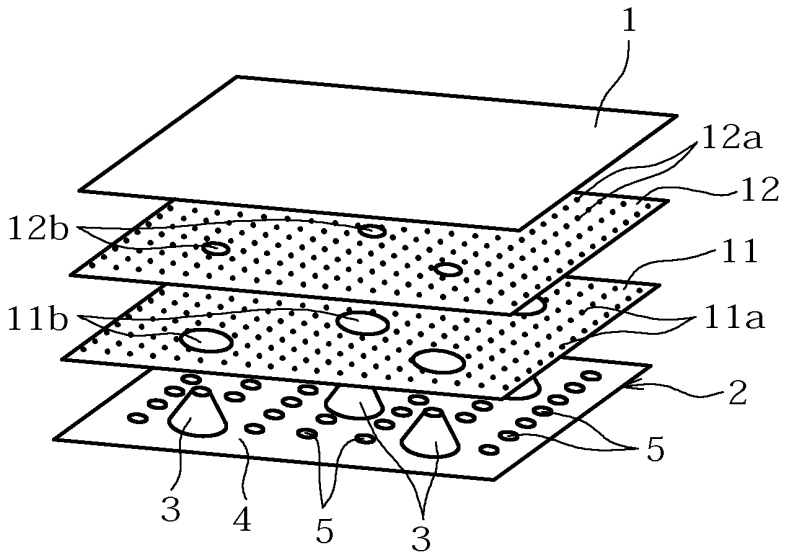


FIG.3

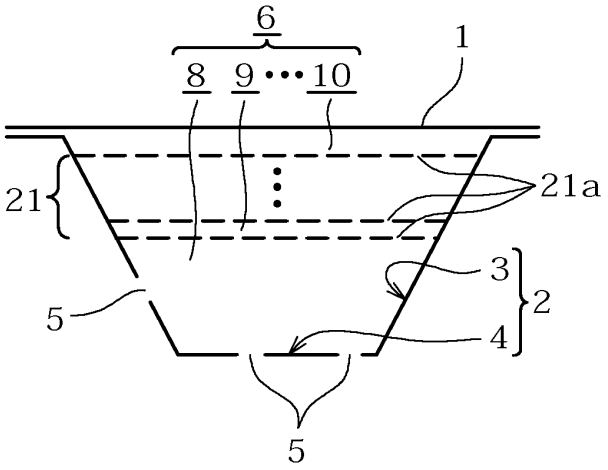



FIG.4

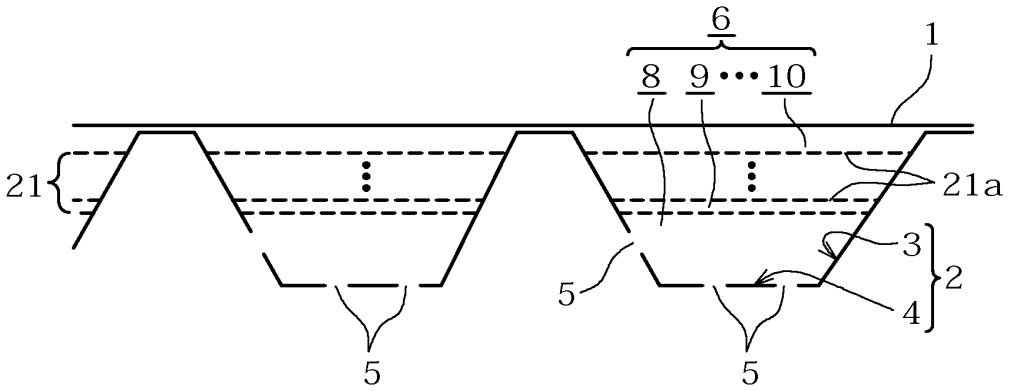



FIG.5

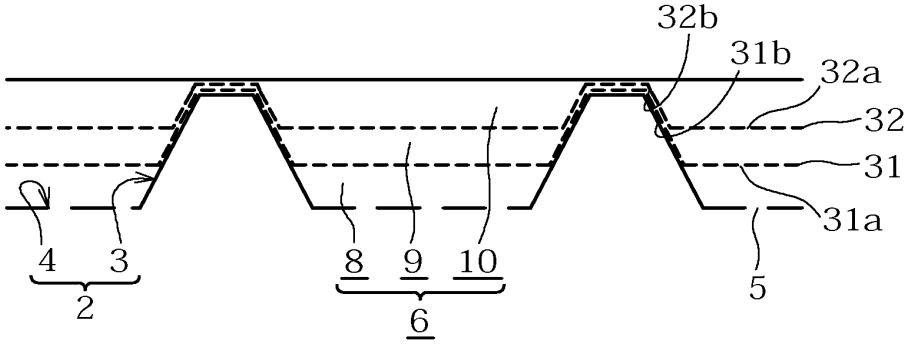
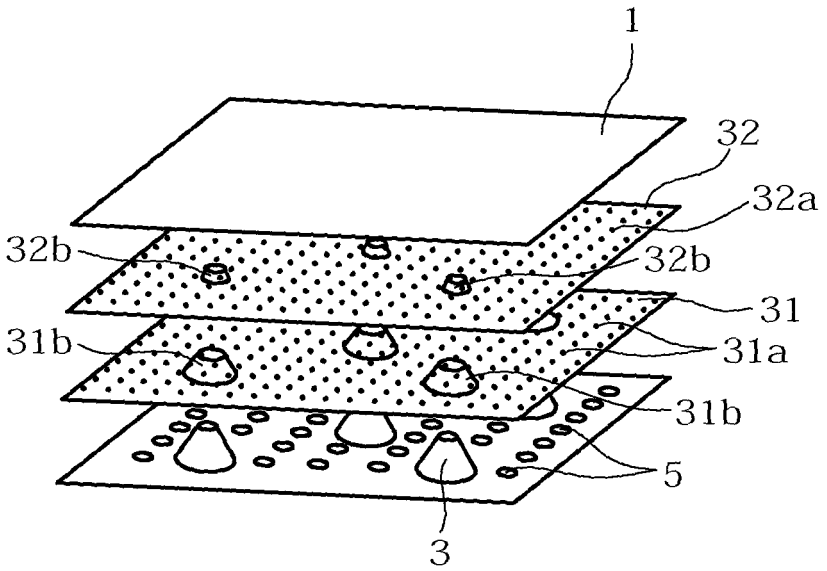


FIG.6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32b
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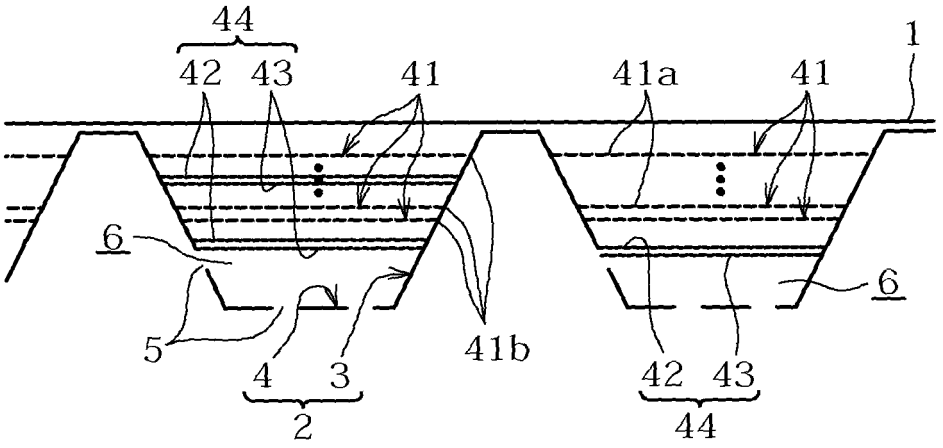
31a
31b
5
3

FIG.7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44

FIG.8

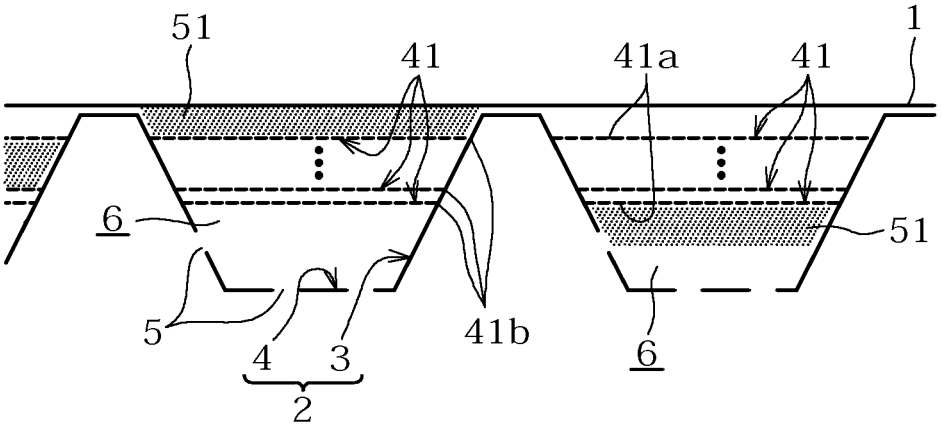


FIG.9

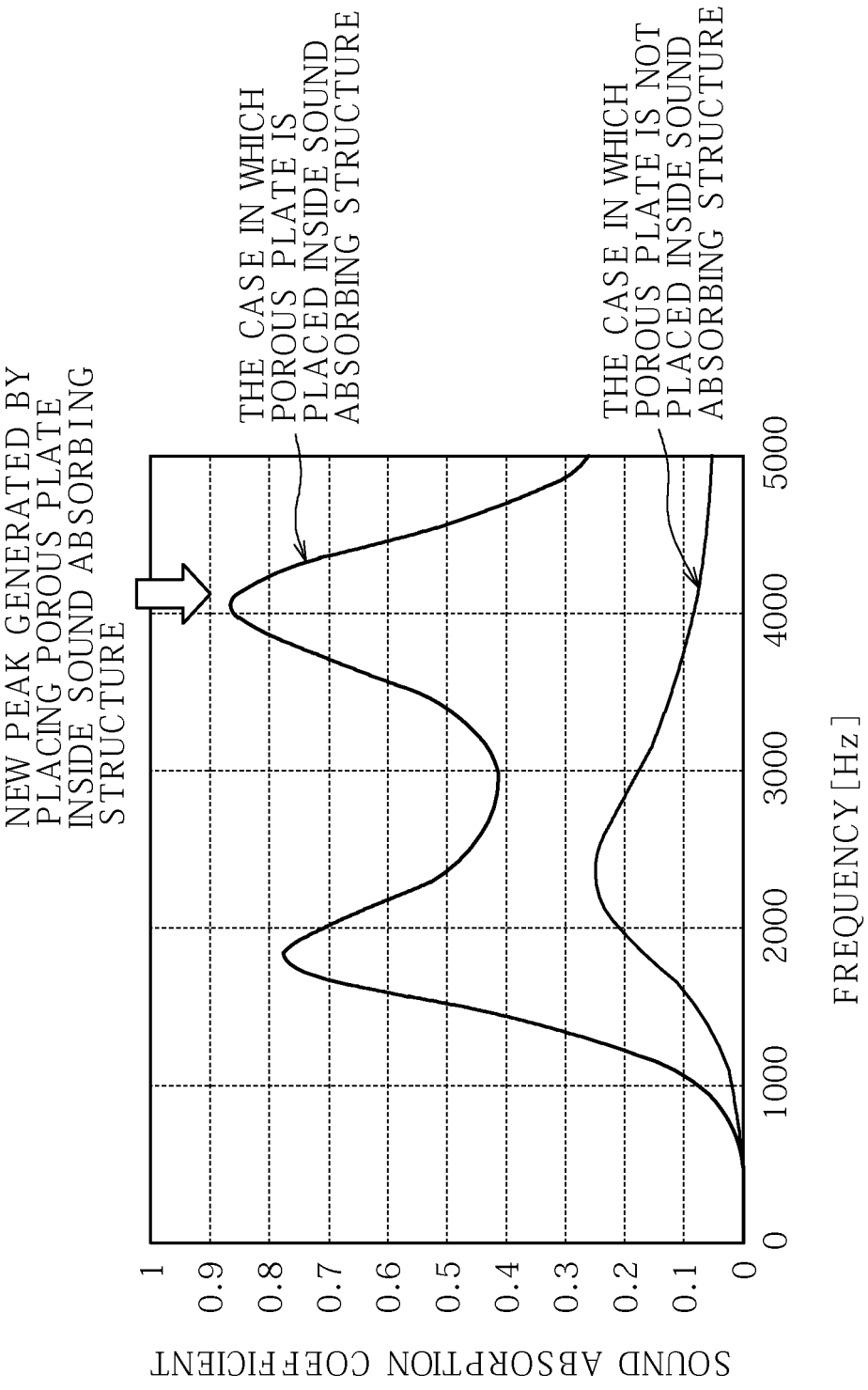

NEW PEAK GENERATED BY PLACING POROUS PLATE INSIDE SOUND ABSORBING STRUCTURE
THE CASE IN WHICH POROUS PLATE IS PLACED INSIDE SOUND ABSORBING STRUCTURE
THE CASE IN WHICH POROUS PLATE IS NOT PLACED INSIDE SOUND ABSORBING STRUCTURE
SOUND ABSORPTION COEFFICIENT
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1000
2000
3000
4000
5000
FREQUENCY [Hz]

FIG.10

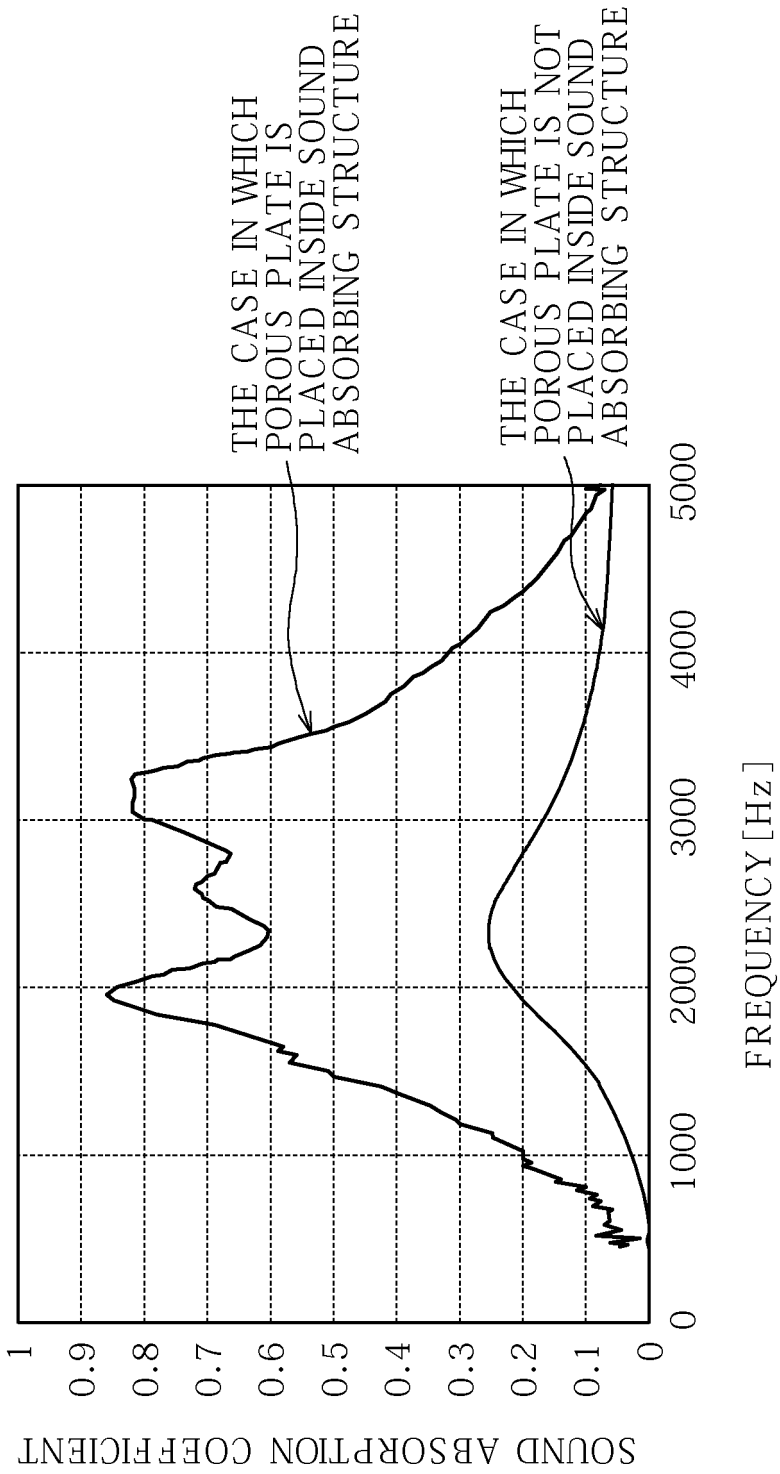

THE CASE IN WHICH POROUS PLATE IS PLACED INSIDE SOUND ABSORBING STRUCTURE
THE CASE IN WHICH POROUS PLATE IS NOT PLACED INSIDE SOUND ABSORBING STRUCTURE
SOUND ABSORPTION COEFFICIENT
FREQUENCY [Hz]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
1000
2000
3000
4000
5000

FIG.11

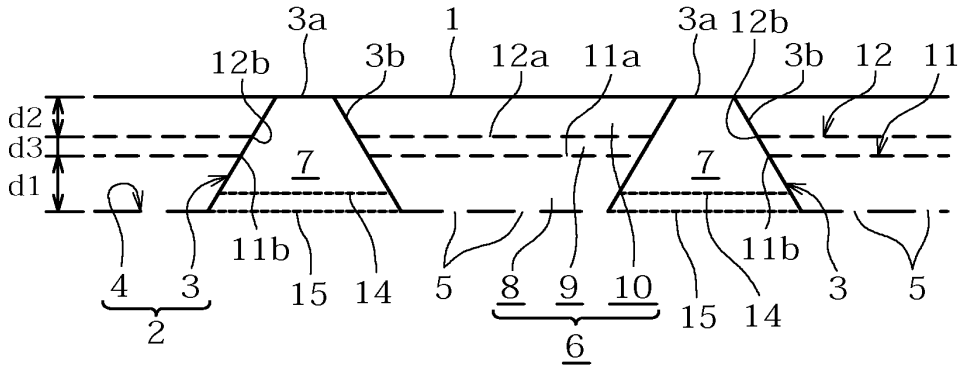



FIG.12

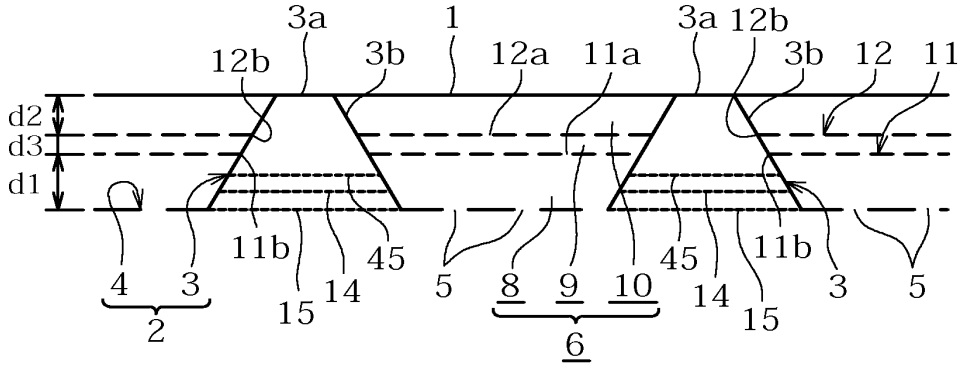



FIG.13

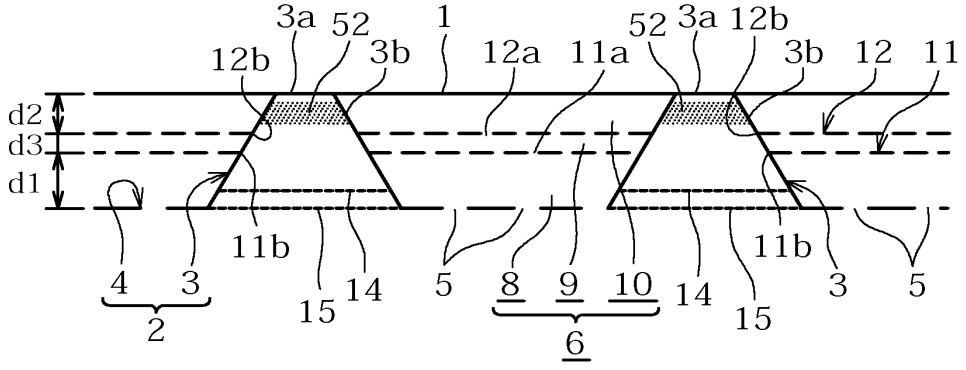
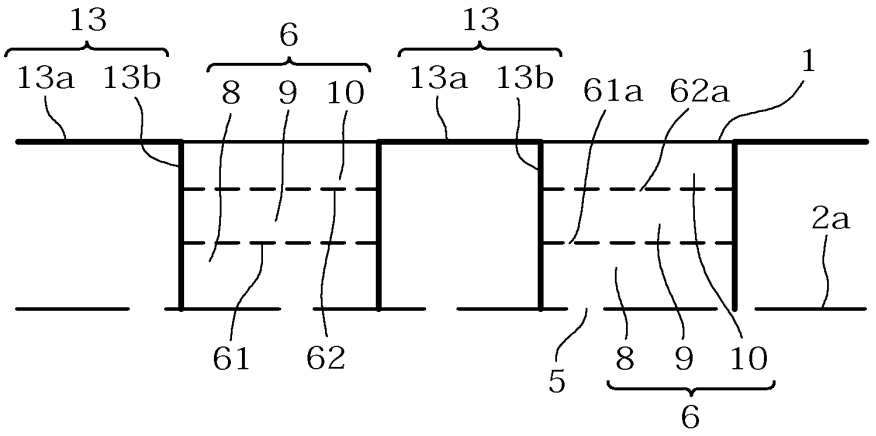


FIG.14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13a 13b
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2a
61 62
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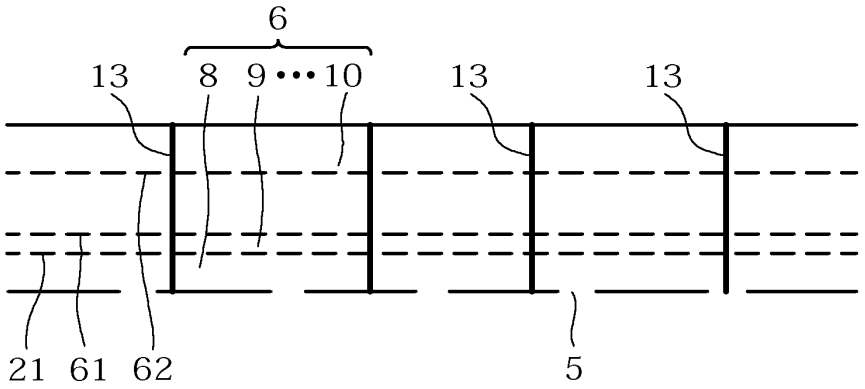
8 9 10
6
SOUND SOURCE SIDE

FIG.15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21 61 62
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SOUND SOURCE SIDE

FIG.16

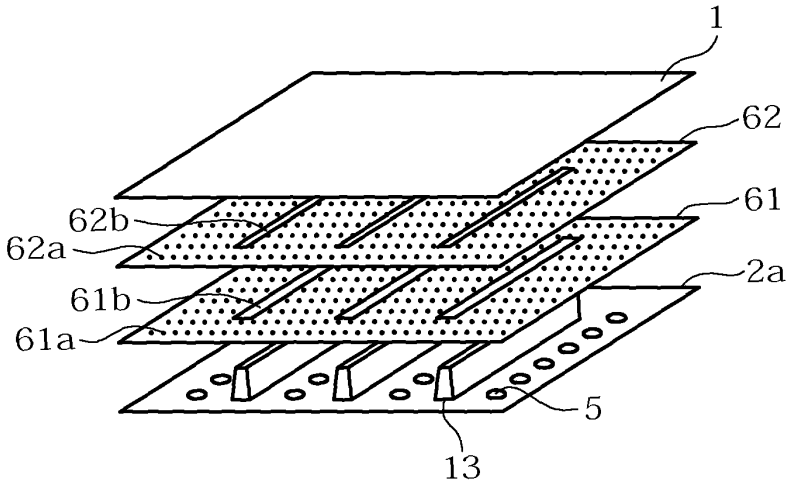
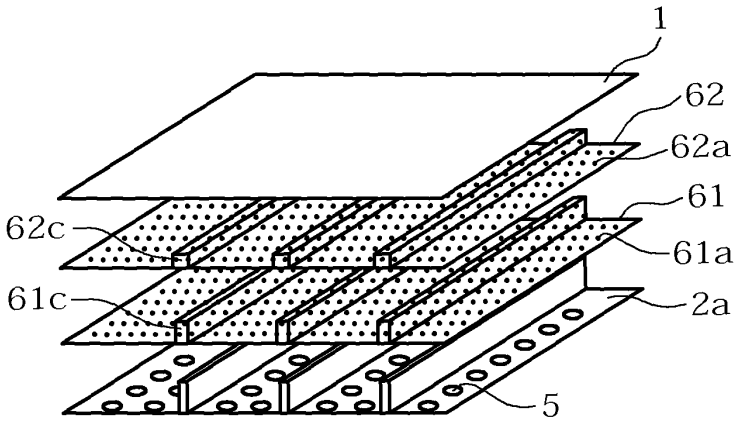



FIG.17



**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2004/012564

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] G10K11/16

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)
Int.Cl[7] G10K11/16, B60R13/02, E04B1/86

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

| | | | |
|---|---|---|---|
| Jitsuyo Shinan Koho | 1922-1996 | Toroku Jitsuyo Shinan Koho | 1994-2004 |
| Kokai Jitsuyo Shinan Koho | 1971-2004 | Jitsuyo Shinan Toroku Koho | 1996-2004 |

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. |
|---|---|---|
| A | JP 55-116942 A (Nippon Sheet Glass Co., Ltd.), 08 September, 1980 (08.09.80), Full text; all drawings (Family: none) | 1-39 |
| A | WO 99/44816 A (M.FAIST GMBH & CO. KG), 10 September, 1999 (10.09.99), Full text; all drawings & DE 298003674 U & EP 1060073 A & PL 342630 A & JP 2002-505208 A | 1-39 |
| A | JP 8-166787 A (NOK Megurasuteikku Kabushiki Kaisha), 25 June, 1996 (25.06.96), Full text; all drawings (Family: none) | 1-39 |

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

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

| | |
|---|---|
| Date of the actual completion of the international search<br>19 November, 2004 (19.11.04) | Date of mailing of the international search report<br>07 December, 2004 (07.12.04) |
| Name and mailing address of the ISA/<br>Japanese Patent Office<br><br>Facsimile No. | Authorized officer<br><br>Telephone No. |

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**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2004/012564

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | JP 2000-16189 A (Mitsubishi Motors Corp.), 18 January, 2000 (18.01.00), Full text; all drawings (Family: none) | 1-39 |

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