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(71) Applicant: **Kabushiki Kaisha Kobe Seiko Sho (Kobe Steel, Ltd.)**
Kobe-shi, Hyogo 651-8585 (JP)

(72) Inventors:
• **YAMAGUCHI Zenzo**
Kobe-shi, Hyogo 651-2271 (JP)
• **YAMAGIWA Ichiro**
Kobe-shi, Hyogo 651-2271 (JP)

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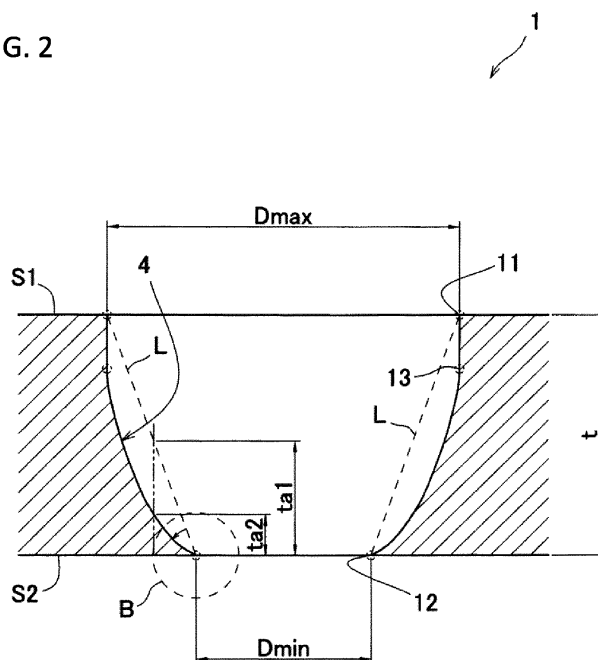
(74) Representative: **TBK**
Bavariaring 4-6
80336 München (DE)

(54) **PERFORATED PLATE**

(57) This perforated plate is disposed so that air layer is formed between plate-shaped or wall-shaped blocking components and the perforated plate, and has a number of through holes. A through hole has the maximum diameter portion formed on one surface of the perforated plate and the minimum diameter portion formed on the

other surface of the perforated plate. The through hole expands outward from a straight line connecting the maximum diameter portion and minimum diameter portion in cross-sectional view along the thickness direction of the perforated plate.

FIG. 2



Description

Technical Field

5 **[0001]** The present invention relates to a perforated plate.

Background Art

10 **[0002]** For example, Patent Literature 1 discloses a technique about a perforated plate as a sound-insulating material for a vehicle or the like. In a perforated sound-absorbing structure disclosed in Patent Literature 1, reinforcement plate materials each having a large number of through-holes are attached to surfaces of an outer material and an inner material on the side of a hollow portion respectively so as to form an air layer between those surfaces. Sound absorbability can be imparted to the inside of the hollow portion due to the reinforcement plate materials having a large number of through-holes. In the perforated sound-absorbing structure, a frequency range of high sound-absorptivity can be widened easily
15 without attaching a fibrous sound-absorbing material to a lower surface of the inner material.

Citation List

Patent Literature

20 **[0003]** Patent Literature 1: JP-A-2014-48632

Summary of the Invention

25 Technical Problems

[0004] In Patent Literature 1, there is no direct suggestion about specific detailed shapes of through-holes formed in each reinforcement plate material. As for a method for perforating the reinforcement plate material, punching is referred to in Paragraph 0054 of Patent Literature 1. A hole made by punching is formed as a hole having a columnar shape whose sectional area is same from the front surface to back surface of the plate material. That is, it can be said that
30 Patent Literature 1 discloses a perforated plate having a large number of holes having columnar shapes each having the same sectional area from the front surface to back surface of the plate material.

[0005] When a perforated plate is used as a sound-insulating material for a vehicle or the like, it is preferable that the number of through-holes formed in the perforated plate is reduced regardless of whether the perforated plate is used as a reinforcement plate or not. When a large number of through-holes are made in the plate, strength of the plate deteriorates. On the other hand, when the number of through-holes is simply reduced, sound absorbability deteriorates. In addition, when the number of through-holes is increased, there arises another problem that the perforating cost is increased. Further, when the number of through-holes is increased excessively, there arises another problem that through-holes adjacent to each other interfere with each other.

40 **[0006]** The present invention has been made in consideration of the aforementioned situation. An object of the present invention is to provide a perforated plate capable of obtaining high sound absorbability with a smaller number of through-holes than that of the through-holes in conventional cases.

Solution to Problems

45 **[0007]** In the present invention, provided is a perforated plate including a large number of through-holes, the perforated plate being placed so that an air layer can be formed between the perforated plate and a plate-shaped or wall-shaped closing member. The through-hole includes a largest hole diameter portion that is formed in one surface of the perforated plate, and a smallest hole diameter portion that is formed in the other surface of the perforated plate; and in a sectional
50 view in a plate thickness direction of the perforated plate, the through-hole swells outside a straight line connecting the largest hole diameter portion and the smallest hole diameter portion.

Advantageous Effects of the Invention

55 **[0008]** Each through-hole is formed into a shape swelling outside a straight line connecting a largest hole diameter portion and a smallest hole diameter portion. Thus, thickness in any part of the through-hole in a plate thickness direction (which is a direction in which sound waves pass) affecting propagation of the sound waves can be made smaller than the case where the sectional shape of each hole is formed by a straight line. That is, in the shape of the through-hole

in the present invention, thickness in any part of the through-hole in the plate thickness direction is smaller than that in a through-hole whose sectional shape is formed by a straight line, when the two through-holes are compared with each other at the parts having the same hole diameter. It is therefore possible to obtain high sound absorbability in spite of a reduced number of through-holes.

Brief Description of the Drawings

[0009]

[FIG. 1] A sectional view showing a perforated sound-absorbing structure including a perforated plate in an embodiment of the present invention.

[FIG. 2] An enlarged view of a part of a through-hole in the perforated plate shown in FIG. 1.

[FIG. 3] A graph showing a relation between flow resistance of the perforated plate and a frequency of a sound wave.

[FIG. 4] A sectional view showing two embodiments of through-holes in the perforated plate.

[FIG. 5] A sectional view showing an embodiment of a through-hole in the perforated plate.

[FIG. 6] A graph showing a comparison result as to sound absorbability between a through-hole 7 shown in FIG. 4 and a through-hole having no swelling in the comparative example.

[FIG. 7] A graph showing a comparison result as to the number of holes having the same sound absorbability between each of the through-holes 6 and 7 shown in FIG. 4 and the through-hole having no swelling in the comparative example.

Description of Embodiments

[0010] Embodiments of the present invention will be described below with reference to the drawings.

(Sound-Absorbing Structure Using Perforated Plate)

[0011] As shown in FIG. 1, a perforated plate 1 in an embodiment of the present invention is placed at a predetermined distance from a plate-shaped or wall-shaped closing member 2 so that an air layer 3 is formed between the perforated plate 1 and the closing member 2. The air layer 3 communicates with the outside only through a large number of through-holes 4 of the perforated plate 1. That is, ends of the perforated plate 1 are, for example, connected to the closing member 2, and they are closed by plates having no through-holes or the like.

[0012] The closing member 2 is a member where no holes are made, that is, a front surface thereof does not communicate with a back surface thereof. In addition, the closing member 2 is placed on the opposite side to a noise source 5 across the perforated plate 1.

[0013] Examples of materials of the perforated plate 1 and the closing member 2 may include aluminum, aluminum alloys, stainless steel, iron, resin, etc.

(Shape of Through-hole)

[0014] FIG. 2 is an enlarged view of a part of a through-hole 4 in the perforated plate 1 shown in FIG. 1. As shown in FIG. 2, the through-hole 4 has a largest hole diameter portion 11 formed in one surface S1 of the perforated plate 1, and a smallest hole diameter portion 12 formed in the other surface S2. That is, the through-hole 4 is a through-hole whose diameter is different between the front surface and the back surface of the perforated plate 1, and reaches a maximum (Dmax) and a minimum (Dmin) respectively in the front and back surfaces of the hole.

[0015] The Dmin (smallest hole diameter) is equal to or smaller than plate thickness t of the perforated plate 1. The smallest value of the Dmin is 0.01 mm. The hole diameter 0.01 mm is a diameter in which the sound absorbability cannot be improved more due to influence of overdamping. That is, the Dmin (smallest hole diameter) is 0.01 mm or more and equal to or smaller than the plate thickness t .

[0016] The Dmax (largest hole diameter) is a larger diameter than the Dmin (smallest hole diameter), and is smaller than $1/2$ of a hole pitch. The hole pitch is a distance between centers of adjacent holes.

[0017] As shown in FIG. 2 which is a sectional view in the direction of the plate thickness t of the perforated plate 1, the wall surface of the through-hole 4 between the largest hole diameter portion 11 and the smallest hole diameter portion 12 is put on a radially outer side from a straight line L connecting the largest hole diameter portion 11 and the smallest hole diameter portion 12, that is, a straight line L connecting one edge part of the largest hole diameter portion 11 and one edge part of the smallest hole diameter portion 12 on the same side as the edge part of the largest hole diameter portion 11. That is, the through-hole 4 has a shape swelling on a radially outer side from the straight line L. In addition, the through-hole 4 has a sectional area which is fixed or reduced as approaching the other surface S2 of the

perforated plate 1 where the smallest hole diameter portion 12 is formed, from the one surface S1 of the perforated plate 1 where the largest hole diameter portion 11 is formed. In the embodiment shown in FIG. 2, the sectional area is fixed (the largest sectional area is kept) between the largest hole diameter portion 11 and a wall surface position 13 under the largest hole diameter portion 11, and then reduced gradually and continuously toward the other surface S2.

[0018] In the sectional view in the direction of the plate thickness t of the perforated plate 1, it is the most essential that the through-hole 4 has a shape swelling outside the straight line L connecting the largest hole diameter portion 11 and the smallest hole diameter portion 12. In this configuration, plate thickness ta_2 is smaller than plate thickness ta_1 ($ta_2 < ta_1$) as shown in FIG. 2, when ta_1 designates a plate thickness at a middle point of a through-hole and ta_2 designates a plate thickness where the hole diameter is the same as that at the middle point of the plate thickness ta_1 . In this manner, at any part of the through-hole 4 in the perforated plate 1, the thickness in the plate thickness direction is smaller than that in the hole shown by the straight line L, which does not swell outward, when the two parts of the through-hole are compared at the same hole diameter. To say other words, at any part excluding the both end parts of the hole in the direction of the plate thickness t , a position in the direction of the plate thickness t having the same hole diameter as that in the hole shown by the straight line L is disposed on the smallest diameter side.

[0019] In the sectional view in the direction of the plate thickness t of the perforated plate 1, the wall surface of the hole may be formed by a curve at most parts of the through-hole 4. However, the wall surface of the hole may be formed by a combination of straight lines extending in an up/down direction, in an oblique direction and in a lateral direction (or the sectional area may be discontinuously reduced as going from the surface S1 toward the surface S2). That is, it will go well if the through-hole 4 has a sectional area being same or reduced as going from the surface S1 toward the surface S2. In the sectional view in the direction of the plate thickness t of the perforated plate 1, the wall surface of the through-hole 4 may be formed by a combination of straight lines and curves, or may be formed by a combination of only curves (including a combination of curves having different curvatures), or may be formed by a combination of only straight lines.

[0020] As shown in FIG. 1, of the through-hole 4, a larger hole diameter (sectional area) side may be disposed on the noise source 5 side, or on the contrary, of the through-hole 4, a smaller hole diameter (sectional area) side may be disposed on the noise source 5 side. This reason will be described below. A sound absorbing effect is determined by a pressure loss generated when a sound wave passes through the hole. The pressure loss is determined by the smallest part of the hole. Therefore, a similar sound absorbing effect can be obtained regardless of whether the smaller hole diameter side or the larger hole diameter side is disposed on the noise source 5 side.

[0021] (Reason why thickness in the plate thickness direction at any part of the through-hole 4 is smaller than that in the case of a through-hole having a sectional shape formed by a straight line when the two parts of the through-hole are taken to have the same hole diameter)

[0022] Flow resistance (front and back pressure loss/passing flow rate) in a perforated plate having a large number of through-holes having a columnar shape with the same sectional area from its front surface to its back surface is expressed by the following formula (1).

[Formula 1]

$$R_t = \frac{32\eta_0}{\beta d^2} t \left\{ \sqrt{1 + \frac{d^2 \rho_0 \omega}{256\eta_0}} + \sqrt{\frac{d^2}{8t} \sqrt{\frac{\rho_0 \omega}{\eta_0}}} \right\} \quad \dots \text{Formula (1)}$$

[0023]

R_t : flow resistance

η_0 : viscous resistance of air

β : opening ratio of perforated plate

d : hole diameter

t : plate thickness of perforated plate

ρ_0 : density of air

ω : angular velocity of sound wave (= frequency)

[0024] FIG. 3 is a graph showing a relation between the flow resistance and the frequency. As shown in FIG. 3, when the plate thickness is large, the flow resistance R_t is larger than the case where the plate thickness is small. When the flow resistance R_t is large, it is necessary to increase the opening ratio β (number of holes) in the perforated plate to thereby reduce damping in order to obtain optimum damping. It is therefore necessary to increase the opening ratio β

when the plate thickness is large.

[0025] As described above, when the through-hole 4 is formed into a hole shape swelling outside the straight line L connecting the largest hole diameter portion 11 and the smallest hole diameter portion 12, the thickness in the plate thickness direction at any part of the through-hole 4 is smaller than that in a through-hole having a sectional shape formed by a straight line, when the two parts of the through-hole are compared at parts having the same hole diameter as each other. Thus, the same effect as the case where the plate thickness of the perforated plate is reduced can be obtained. As a result, it is possible to reduce the number of through-holes 4 for obtaining the same sound absorbability. In this manner, it is possible to obtain high sound absorbability with a reduced number of through-holes. Further, there are additional effects of reducing the cost in machining the hole, avoiding interference between adjacent through-holes, and improving strength of the perforated plate.

[0026] A part having great contribution to obtaining the same effect as that when the plate thickness of the perforated plate is reduced is a hole lower part B of the through-hole 4, which is a peripheral part of the smallest hole diameter portion 12 in the through-hole 4. When the hole swells outside the straight line L at the hole lower part B (when the hole is formed into a curve like a concave (or may be formed by a straight line)), the plate thickness can be easily reduced at any part of the through-hole 4 from the surface S1 to the surface S2.

(Other Embodiments)

[0027] FIG. 4 shows two embodiments of through-holes. In the sectional view in the direction of the plate thickness t of the perforated plate 1, of a part swelling outside the straight line L connecting the largest hole diameter portion 11 and the smallest hole diameter portion 12 in the through-hole, a largest swelling position (a position of a largest swelling amount δa in a direction parallel to the surfaces S1 and S2 of the perforated plate 1) is preferably a central position in the direction of the plate thickness t of the perforated plate 1, or a position on the smallest hole diameter portion 12 side from the central position.

[0028] As for a through-hole 6 of two through-holes 6 and 7 shown in FIG. 4, a largest swelling position 14 of the through-hole 6 is set at the central position in the direction of the plate thickness t of the perforated plate 1. As for the other through-hole 7, a largest swelling position 15 of the through-hole 7 (a position of a largest swelling amount δb in a direction parallel to the surfaces S1 and S2 of the perforated plate 1) is set on the smallest hole diameter portion 12 side from the central position in the direction of the plate thickness t and at a position of $1/4 \cdot t$ from the surface S2 on the smallest hole diameter portion 12 side.

[0029] As shown in FIG. 5, in order to ensure satisfactory strength near the smallest hole diameter portion 12, it is preferable to have a structure in which the smallest hole diameter portion 12 has a certain thickness. When the thickness of the smallest hole diameter portion 12 is larger than the hole diameter D_{min} of the smallest hole diameter portion, the effect of improving the sound absorbing performance due to the hole shape of the through-hole swelling outside the straight line connecting the largest hole diameter portion and the smallest hole diameter portion is reduced. Therefore, the thickness t_d of the smallest hole diameter portion 12 is set at a predetermined thickness equal to or smaller than the hole diameter D_{min} of the smallest hole diameter portion 12.

[0030] In this structure, it is possible to ensure satisfactory strength near the smallest hole diameter portion 12 as described above. In addition, there is another effect that the hole can be machined more easily than when the smallest hole diameter portion 12 has a sharp structure.

(Validation Result)

[0031] FIG. 6 is a graph showing a comparison result of sound absorbability between the through-hole 7 shown in FIG. 4 and a through-hole having no swelling in the comparative example (a conical through-hole in which the largest hole diameter portion 11 and the smallest hole diameter portion 12 are connected by the straight line L in sectional view). In FIG. 6, a line indicated as "present invention" designates the through-hole 7 shown in FIG. 4 (an example of the embodiment). The opening ratio in the perforated plate having each through-hole was equally set at 0.5%. As is found from FIG. 6, the sound absorbability can be improved on a larger scale in the through-hole 7 (the perforated plate 1 having a large number of through-holes 7) in the present invention than the case in the through-hole (the perforated plate having through-holes having no swelling) in the comparative example.

[0032] FIG. 7 is a graph showing a comparison result as to the number of holes having the same sound absorbability between each through-holes 6 and 7 shown in FIG. 4 and the through-hole having no swelling in the comparative example (the conical through-hole in which the largest hole diameter portion 11 and the smallest hole diameter portion 12 are connected by the straight line L in sectional view).

[0033] The ordinate in the graph shown in FIG. 7 designates the ratio of the number of through-holes 6 and 7 in the present invention (the perforated plate 1 having a large number of through-holes 6 or 7) when the number of holes in the through-hole having no swelling in the comparative example (the perforated plate having through-holes having no

swelling) is taken as 100%. The abscissa in the graph designates the swelling amount at the largest swelling positions 14 and 15 of each of the through-holes 6 and 7.

[0034] As is found from FIG. 7, the number of through-holes 6 and 7 in the present invention (the perforated plate 1 having a large number of through-holes 6 or 7) can be reduced in comparison with the number of through-holes having no swelling in the comparative example (the perforated plate having through-holes having no swelling), in order to attain the same sound absorbability.

[0035] When the case of the through-hole 6 (the largest swelling position is $1/2 \cdot t$ from the surface S2) is compared with the case of the through-hole 7 (the largest swelling position is $1/4 \cdot t$ from the surface S2), the number of holes can be reduced in the case of the through-hole 7 in order to attain the same sound absorbability. That is, as the largest swelling position is made closer to the smallest hole diameter portion 12, the number of holes can be reduced.

(Operation/Effect)

[0036] Each through-hole in a perforated plate in the present invention includes a largest hole diameter portion that is formed in one surface of the perforated plate, and a smallest hole diameter portion that is formed in the other surface of the perforated plate. In the sectional view in the plate thickness direction of the perforated plate, the through-hole swells outside a straight line connecting the largest hole diameter portion and the smallest hole diameter portion.

[0037] In this configuration, the thickness in the plate thickness direction at any part of the through-hole in the perforated plate can be made smaller than that in a case where the sectional shape of a through-hole is formed by a straight line, when the two parts of the through-hole are compared at places with the same diameter. In this manner, the same effect as that when the plate thickness of the perforated plate is reduced can be obtained. Thus, it is possible to obtain high sound absorbability with a small number of through-holes.

[0038] In addition, in the sectional view in the plate thickness direction of the perforated plate in the present invention, it is preferable that, of the part of the through-hole swelling outside the straight line connecting the largest hole diameter portion and the smallest hole diameter portion, a largest swelling position is a central position in the plate thickness direction of the perforated plate or a position on the smallest hole diameter portion side from the central position. In this configuration, it is possible to obtain high sound absorbability with a smaller number of through-holes.

[0039] In addition, in the present invention, it is preferable that the smallest hole diameter portion has a thickness equal to or smaller than the hole diameter of the smallest hole diameter portion. In this configuration, it is possible to ensure satisfactory strength near the smallest hole diameter portion. In addition, it is also possible to obtain an effect of making it easier to machine the hole than the case where the smallest hole diameter portion is made to have a sharp structure.

[0040] The present application is based on a Japanese patent application No. 2015-101502 filed on May 19, 2015, the contents of which are incorporated herein by reference.

Description of Reference Numerals and Signs

[0041]

- 1: Perforated plate
- 2: Closing member
- 3: Air layer
- 4: Through-hole
- 11: Largest hole diameter portion
- 12: Smallest hole diameter portion
- L: Straight line connecting the largest hole diameter portion 11 and the smallest hole diameter portion 12
- S 1: One surface
- S2: Other surface
- t: Plate thickness

Claims

1. A perforated plate comprising a large number of through-holes, the perforated plate being placed so that an air layer is formed between the perforated plate and a plate-shaped or wall-shaped closing member; wherein:

the through-hole includes a largest hole diameter portion that is formed in one surface of the perforated plate, and a smallest hole diameter portion that is formed in the other surface of the perforated plate; and

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in a sectional view in a plate thickness direction of the perforated plate, the through-hole swells outside a straight line connecting the largest hole diameter portion and the smallest hole diameter portion.

2. The perforated plate according to claim 1, wherein:

5 in the sectional view in the plate thickness direction of the perforated plate, of a part of the through-hole swelling outside the straight line, a largest swelling position is a central position in the plate thickness direction of the perforated plate or a position on the smallest hole diameter portion side from the central position.

- 10 3. The perforated plate according to claim 1 or 2, wherein:

the smallest hole diameter portion has a thickness equal to or smaller than a hole diameter of the smallest hole diameter portion.

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FIG. 1

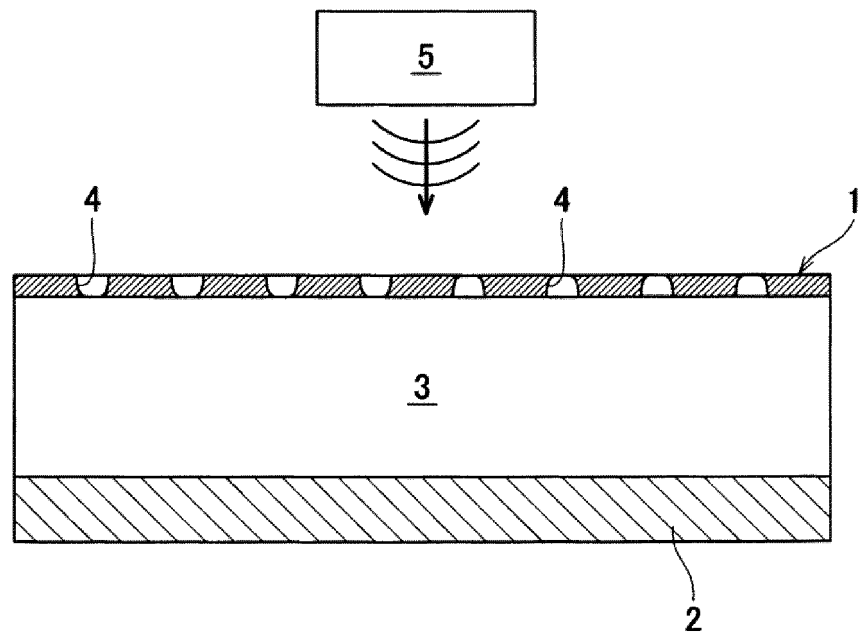


FIG. 2

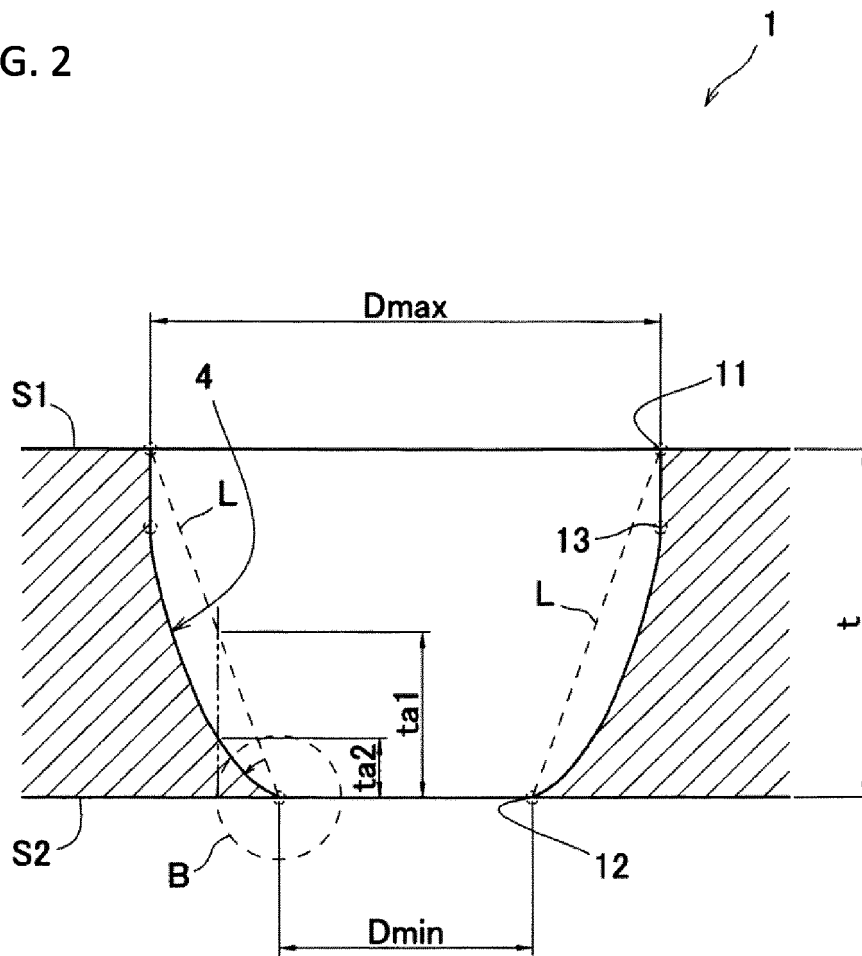


FIG. 3

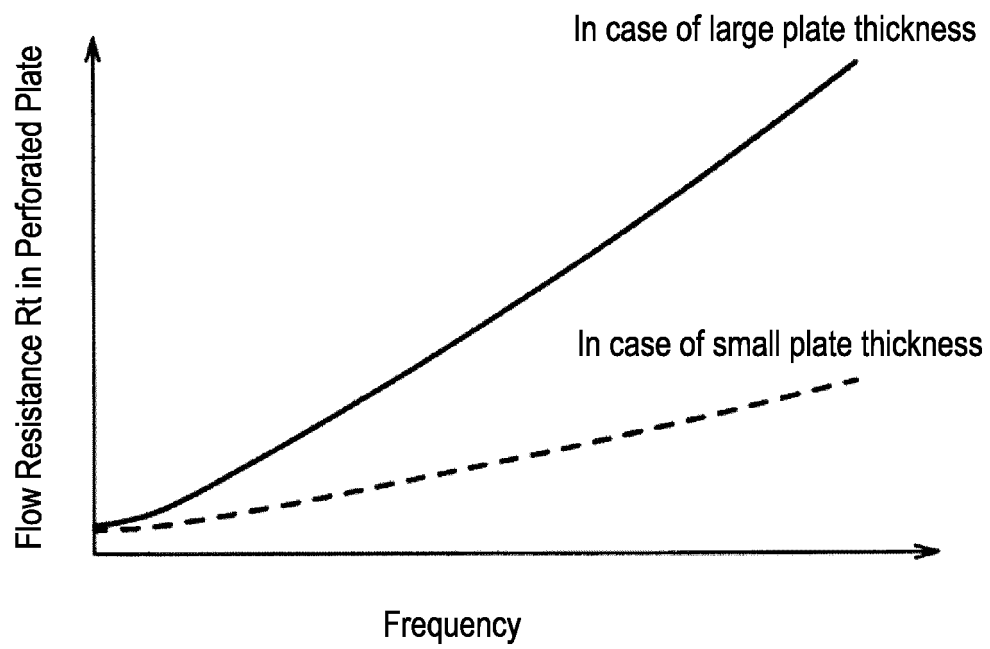


FIG. 4

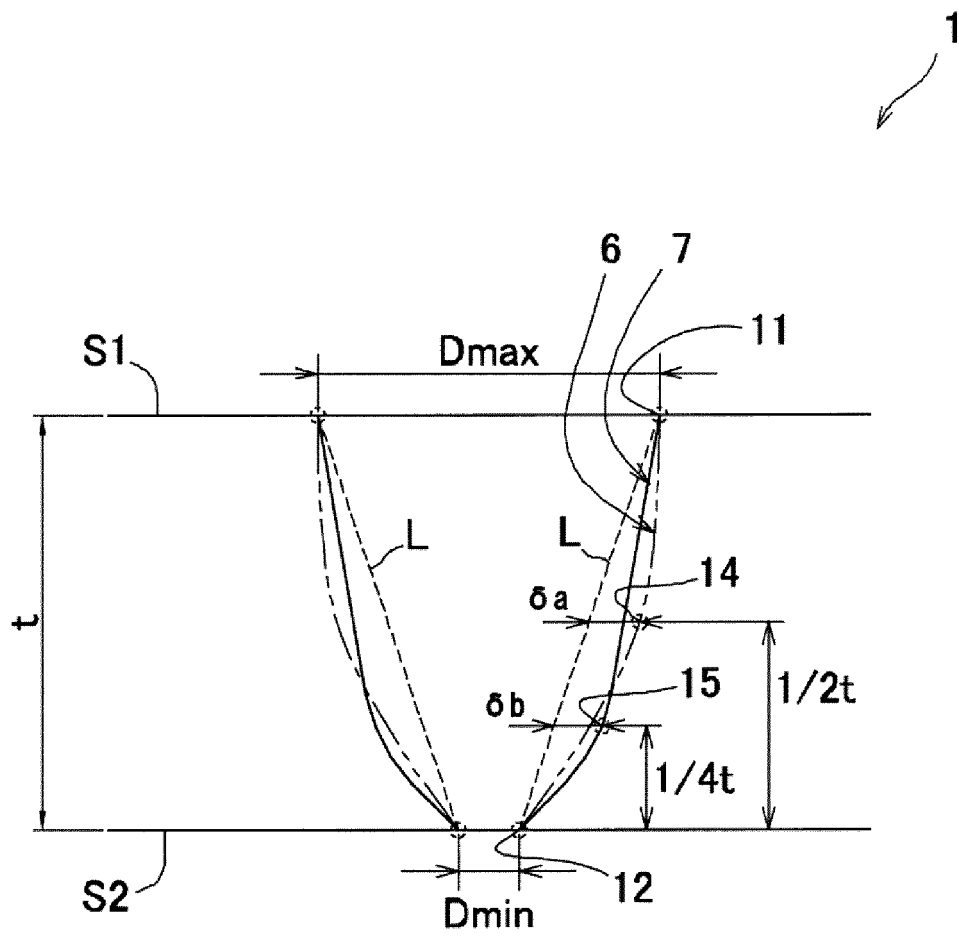


FIG. 5

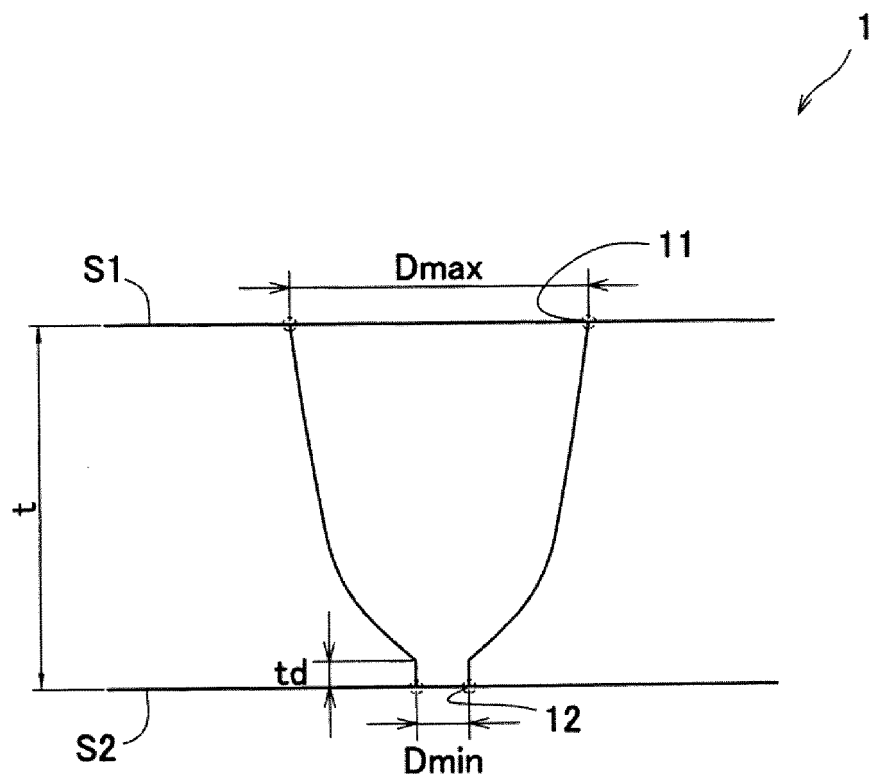


FIG. 6

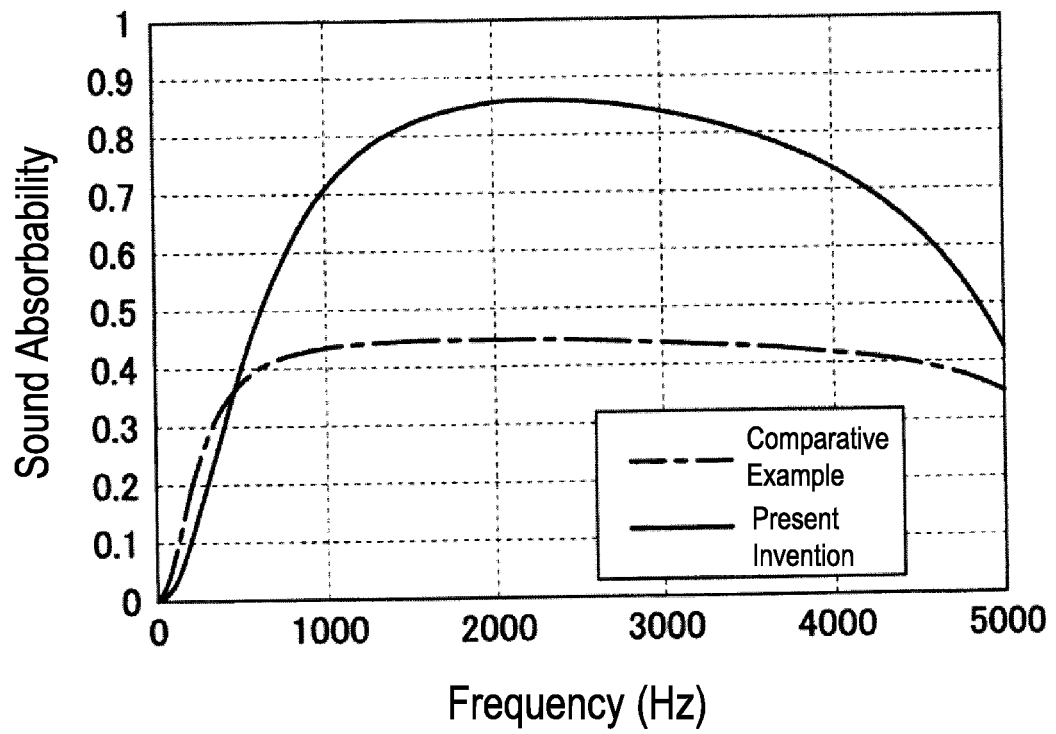
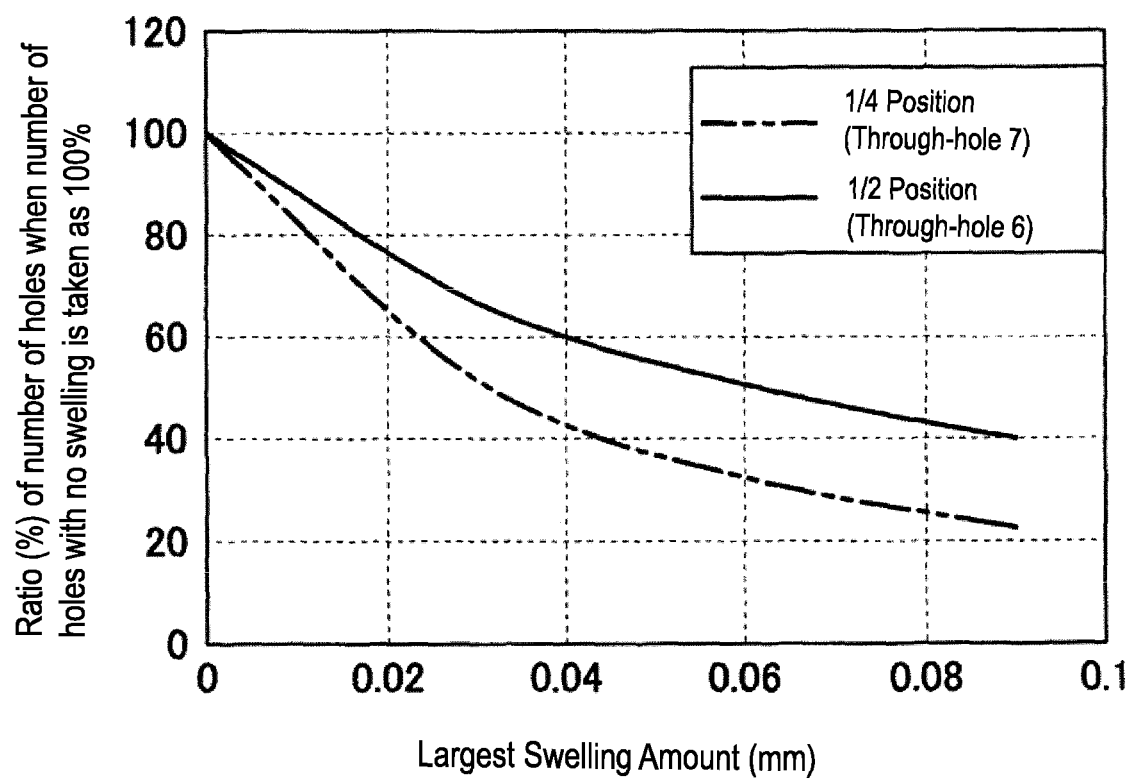


FIG. 7



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/063587

A. CLASSIFICATION OF SUBJECT MATTER

G10K11/172(2006.01)i, B60R13/08(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G10K11/172, B60R13/08

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2016

Kokai Jitsuyo Shinan Koho 1971-2016 Toroku Jitsuyo Shinan Koho 1994-2016

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.
X	JP 52-88301 A (Hiroshi KOTODA),	1, 2
Y	23 July 1977 (23.07.1977), entire text; all drawings (Family: none)	3
Y	JP 2008-544119 A (KIM, Young-Ok), 04 December 2008 (04.12.2008), entire text; all drawings & US 2009/0038883 A1 entire text; all drawings & WO 2006/135164 A1 & KR 10-0645824 B1 & CN 101194077 A	3

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

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Date of the actual completion of the international search
30 June 2016 (30.06.16)Date of mailing of the international search report
12 July 2016 (12.07.16)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2014048632 A [0003]
- JP 2015101502 A [0040]