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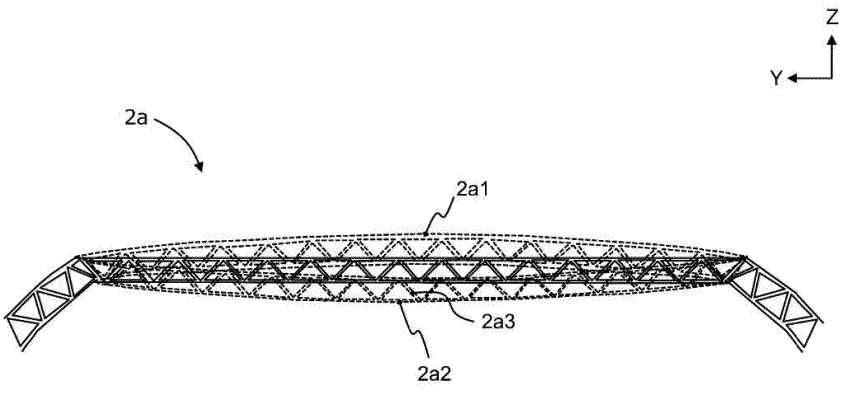
(54) RAIL VEHICLE

(57) A railway vehicle has a double skin structure including a vehicle exterior side face plate, a vehicle interior side face plate, connection plates, and cavities surrounded thereby. The vehicle interior side face plate of the double skin structure is provided with a sound absorbing material, and is further covered with an interior panel. Holes are formed on the vehicle interior plate surface side of the double skin structure of the region where a thickness t of a space between the vehicle interior side face plate of the double skin structure and the interior panel is such that $t \leq 3L$ with respect to a structure thickness L of the double skin structure. This allows sound insulation performance to be improved in a region most effective in reducing vehicle interior noise without reducing the passenger room space.

FIG. 5



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Description

Technical Field

[0001] The present invention relates to a rail vehicle.

Background Art

[0002] In rail vehicles, particularly high-speed railway vehicles, it is indispensable to reduce noise in a passenger room, which increases with the speedup, in order to secure comfortable movement of passengers. For this reason, various vehicle interior noise reduction techniques have been conventionally developed. On the other hand, in recent years, a structure referred to as a double skin structure has been often adopted as a lightweight, high-strength, and highly manufacturable vehicle body structure.

[0003] This double skin structure has a hollow truss structure including a pair of opposing outer and inner plates and a connection plate for connecting these plates, and has an advantage of being lightweight and having high bending rigidity. Further, since the double-skin structure can be formed by using an extruded shape material having the same cross-sectional structure in the vehicle longitudinal direction, the double skin structure has an advantage of being excellent also in manufacturability.

[0004] As a technique for improving sound insulation performance using the double skin structure, for example, PTL 1 is disclosed. This known example describes a method in which forming a hole portion in one or both of the inner plate and the connection plate of the double skin structure and further arranging a sound absorbing material between the inner plate on the in-vehicle side and the interior panel of the railway vehicle improves sound insulation performance.

Citation List

Patent Literature

[0005] PTL 1: JP 2017-105228 A

Summary of Invention

Technical Problem

[0006] In PTL 1 described above, the position, condition, and the like of the drilled region of the double skin structure are not clearly shown. For example, if the thickness of the sound absorbing material is sufficient, it can be said that the effect of providing the hole portion by increasing the number of machining steps is small. In addition, even if a hole portion is provided in the double skin structure, further improvement is also expected to achieve both strength and securing of sound insulation performance at a high level.

[0007] For example, in order to prevent a decrease in strength caused by providing a hole portion in the inner plate of the double skin structure for securing sound insulation performance, it is one idea to give a margin to the plate thickness, but relying on that alone will cause a significant increase in costs. On the other hand, increasing the number of hole portions instead of reducing the cross-sectional area of the hole portions allows the same sound insulation performance to be secured while a decrease in strength is prevented, but this leads to an increase in the number of machining steps for drilling. Furthermore, there is also a problem that it is difficult to provide a hole portion depending on the load condition and the structure and region of the double skin structure.

[0008] In addition, there is also a problem related to the sound absorbing material disposed on the inner surface of the double skin structure. Conventionally, in some cases, a method of bonding a sound absorbing material to an inner plate of a double skin structure using a double-sided tape previously pasted on one surface of the sound absorbing material is adopted.

[0009] Here, even when a double-sided tape without air permeability is used, in order to achieve a sufficient sound insulation performance improvement effect, it is preferable to avoid hole portions drilled in the inner plate and to provide the double-sided tape. However, since the position at which the double-sided tape is provided is limited, there is a possibility that time and effort of the work may increase.

[0010] An object of the present invention is to provide a rail vehicle capable of preventing a decrease in strength and an increase in the number of machining steps that can be caused by drilling a hole in a vehicle interior side face plate of a double skin structure, the rail vehicle having an excellent sound insulation effect.

Solution to Problem

[0011] In order to solve the above problems, one of the typical rail vehicles of the present invention is a rail vehicle including:

a double skin structure including:
a vehicle interior side face plate,
a vehicle exterior side face plate, and
a connection plate configured to connect the vehicle interior side face plate and the vehicle exterior side face plate,
a sound absorbing material provided on the vehicle interior side face plate, and
an interior material configured to cover the sound absorbing material,
the rail vehicle including a plurality of holes penetrating the vehicle interior side face plate, and
an interval t between the vehicle interior side face plate and the interior material being not more than three times a thickness dimension L of the double skin structure.

Advantageous Effects of Invention

[0012] According to the present invention, it is possible to provide a rail vehicle capable of preventing a decrease in strength and an increase in the number of machining steps that can be caused by drilling a hole in a vehicle interior side face plate of a double skin structure, the rail vehicle having an excellent sound insulation effect.

[0013] Problems, configurations, and effects other than those described above will be clarified by the following description of embodiments.

Brief Description of Drawings

[0014]

[FIG. 1] FIG. 1 is a cross-sectional view intersecting the longitudinal direction of a railway vehicle mounting an air conditioner on a roof.

[FIG. 2] FIG. 2 is a cross-sectional view intersecting the longitudinal direction of a railway vehicle mounting a current collector on a roof.

[FIG. 3] FIG. 3 is a partially enlarged view of a roof structure on which an air conditioner is placed (see FIG. 1) .

[FIG. 4] FIG. 4 is a partially enlarged view of a roof structure on which a current collector is placed (see FIG. 2) .

[FIG. 5] FIG. 5 is a diagram schematically illustrating a primary vibration mode of a roof structure having a double skin structure.

[FIG. 6] FIG. 6 is a diagram schematically illustrating a secondary vibration mode of a roof structure having a double skin structure.

[FIG. 7] FIG. 7 is a schematic diagram illustrating a model of a double wall structure including an equivalent rigid plate corresponding to a double skin structure, a sound absorbing heat insulating material having an air layer, and an interior material.

[FIG. 8] FIG. 8 is a schematic diagram illustrating a change in transmission loss when the thickness of the sound absorbing heat insulating material having an air layer shown in FIG. 7 is changed.

[FIG. 9] FIG. 9 is a perspective view of a roof structure provided with holes in a face plate on the vehicle interior side.

[FIG. 10] FIG. 10 is a cross-sectional view illustrating a state in which a sound absorbing material and an interior panel are arranged on the vehicle interior side of a roof structure provided with holes in a face plate on the vehicle interior side.

[FIG. 11] FIG. 11 is a perspective view of a roof structure provided with a hole in a region including a plate thickness portion of a face plate on the vehicle interior side.

[FIG. 12] FIG. 12 is a cross-sectional view illustrating a state in which a sound absorbing material and an interior panel are arranged on the vehicle interior side of a roof structure provided with a hole in a region including a plate thickness portion of a face plate on the vehicle interior side.

[FIG. 13] FIG. 13 is a perspective view of a roof structure provided with a hole at a joint portion between a face plate on the vehicle interior side and a connection plate for connecting the face plates inside and outside the vehicle.

[FIG. 14] FIG. 14 is an enlarged cross-sectional view of a roof structure including a hole at a joint portion between a face plate on the vehicle interior side and a connection plate for connecting the face plates inside and outside the vehicle.

[FIG. 15] FIG. 15 is a perspective view of a roof structure provided with holes only in the face plate near the curtain rail structure of the vehicle interior side face plate having the curtain rail structure.

[FIG. 16] FIG. 16 is a cross-sectional view illustrating a state in which a sound absorbing material and an interior panel are arranged on the vehicle interior side of a roof structure provided with holes only in the face plate near the curtain rail structure of the vehicle interior side face plate having the curtain rail structure.

Description of Embodiments

[0015] Hereinafter, embodiments of the present invention will be described with reference to the drawings. First, each direction is defined. The longitudinal (rail) direction of the railway vehicle structures 1a and 1b is represented as X direction, their width (ties) direction is represented as Y directions, and their height direction is represented as Z direction, and they may be simply represented as X direction, Y direction, and Z direction.

[0016] A rail vehicle is a vehicle to be run along a track to be laid, and includes a railway vehicle, a monorail vehicles, a tram, and a new transportation vehicle. An embodiment of the present invention will be described by taking up a railway vehicle as a typical example of a rail vehicle. The present invention is applicable not only to high-speed rail vehicles but also to all rail vehicles. Hereinafter, the present invention will be described with reference to a railway vehicle as a representative of a rail vehicle.

[0017] FIG. 1 is a cross-sectional view intersecting the longitudinal direction of a railway vehicle mounting an air conditioner on a roof, and FIG. 2 is a cross-sectional view intersecting the longitudinal direction of a railway vehicle mounting a current collector on a roof. The railway vehicle structure 1a (1b) is generally a hexahedron including a floor structure (underframe) 4 that forms the floor surface, side structures 3 erected at both end portions in the Y direction of the floor structure 4, a roof structure 2a (2b) placed on the upper end portion of the side structure 3, and end structures (not shown) provided at both end portions of the floor structure 4 in the X direction.

[0018] With reference to FIGS. 3 and 4, the floor struc-

ture 4, the side structure 3, and the roof structure 2a or 2b are double skin structures including a vehicle exterior side face plate (also referred to as outer plate) 2a1 or 2b1 and a vehicle interior side face plate (also referred to as inner plate) 2a2 or 2b2, and a connection plate 2a3 or 2b3 for connecting these face plates. With reference to FIG. 10, these double skin structures includes a vehicle exterior side cavity 20 being a space surrounded by the vehicle exterior side face plate 2b1 and the two adjacent connection plates 2b3, and a vehicle interior side cavity 17 being a space surrounded (partitioned) by the vehicle interior side face plate 2b2 and the two adjacent connection plates 2b3.

[0019] Here, a structure made of a hollow extruded shape material including two opposing face plates and a connection plate connecting these face plates is referred to as a double skin structure. The double skin structure has characteristics of being lightweight, high-strength, and highly manufacturable.

[0020] The double skin structure is made of an aluminum alloy and made of a hollow extruded shape material extruded in the X direction. These shape materials are arranged in the Y direction, and then the butted portions in the Y direction are joined along the X direction to form the floor structure 4, the side structure 3, and the roof structure 2a (2b), so that it is possible to reduce the manufacturing cost even though having a complicated configuration.

[0021] As shown in FIG. 1, an air conditioner 5 is placed on the central portion side in the X direction of the railway vehicle structure 1a, and as shown in FIG. 2, a current collector (pantograph) 6 is placed on the low roof portion on the end portion side in the X direction of the railway vehicle structure 1b. On the vehicle interior side of the railway vehicle structure 1a (1b), an interior panel (interior material) 7, an air-conditioning duct 8, a floor plate 10, a seat 11, a load shelf 12, and the like are provided.

[0022] FIG. 3 is a partially enlarged view of a roof structure on which an air conditioner is placed (see FIG. 1), and FIG. 4 is a partially enlarged view of a roof structure on which a current collector is placed (see FIG. 2).

[0023] The roof structure 2a (see FIG. 3) is a double skin structure including an outer plate 2a1, an inner plate 2a2, and a connection plate 2a3 connecting these plates. In this example, the inner plate 2a2 of the double skin structure has a curtain rail structure 13 extruded integrally with the inner plate 2a2 in advance, and the interior panel 7, the air-conditioning duct 8, and the like are fixed to the curtain rail structure 13. The curtain rail structure refers to a structure having a substantially C-shaped cross section in the longitudinal direction. An embodiment including the curtain rail structure 13 will be described below with reference to FIGS. 15 and 16.

[0024] In addition, a sound absorbing material 14 also having heat insulation or the like is provided between the inner plate 2a2 of the double skin structure and the top plate 8a of the interior panel 7 and the air conditioning duct 8.

[0025] The sound absorbing material 14 uses, for example, a foamed material, a fiber based sound absorbing material, or the like, and is pasted on the inner plate 2a2 of the double skin structure with an adhesive or a double-sided tape. An opening 8c for blowing the air-conditioned air into the vehicle interior is provided on a side surface 8b of the air-conditioning duct 8. In addition, in FIG. 4 being an enlarged view of the ceiling portion in a cross section of the low roof portion (see FIG. 2), the sound absorbing material 14 is provided on the inner plate 2b2 side of the roof structure 2b, and the sound absorbing material 14 is covered with the interior panel 7.

[0026] Generally, in the air conditioner 5 and the current collector 6 on the roof, aerodynamic noise is generated by the air on the roof of the railway vehicle running at high speed being disturbed, and the aerodynamic noise increases abruptly as the vehicle speed increases, so that the air conditioner 5 and the current collector 6 become large noise sources especially when the train runs at high speed. The aerodynamic noise generated on the roof is transmitted through the roof structure 2a or 2b, the sound absorbing material 14, the interior panel 7, the top plate 8a of the air-conditioning duct, and the like, and is transmitted to the vehicle interior, thereby being a factor that increases the vehicle interior noise.

[0027] Here, the aerodynamic noise has a relatively large low frequency component, and the sound insulation characteristics of the vehicle body and the sound absorption characteristics of the vehicle interior space are generally low in the low frequency range. Therefore, it is common to take measures against noise on the premise that a low frequency range of 1 kHz or less is dominant in vehicle interior noise. In other words, it is particularly important to improve the sound insulation performance in a low frequency range.

[0028] It should be noted that as shown in FIG. 3, an opening 8c for blowing the air-conditioned air into the vehicle interior is provided on a side surface 8b of the air-conditioning duct 8. However, since the noise transmitted through the top plate 8a is transmitted to the vehicle interior through the opening 8c, first, it is desirable to reduce the noise transmitted through the top plate 8a.

[0029] In such a situation, in order to improve the sound insulation performance in the low frequency range, it is known to be effective to widen the space between the inner plate 2a2 or 2b2 of the double skin structure and the interior panel 7 or the top plate 8a, or to increase the weight of these interior panels.

[0030] FIG. 5 is a diagram schematically illustrating a primary vibration mode of a roof structure having a double skin structure, and FIG. 6 is a diagram schematically illustrating a secondary vibration mode of a roof structure having a double skin structure. FIG. 7 is a schematic diagram illustrating a model of a double wall structure including an equivalent rigid plate corresponding to a double skin structure, a sound absorbing heat insulating material having an air layer, and an interior material, and FIG. 8 is a schematic diagram illustrating a change in

transmission loss when the thickness of the sound absorbing heat insulating material having an air layer is changed.

[0031] Since the double skin structure is generally lightweight and highly rigid, the natural frequency of the bending mode of the plate exists at a relatively high frequency, and at low frequencies not more than 1 kHz, the primary vibration mode with a long wavelength (see FIG. 5) or the secondary vibration mode (see FIG. 6) is dominant.

[0032] As described above, in the low-order vibration modes, the outer plate 2a1, the inner plate 2a2, and the connection plate 2a3, which form a double skin structure, vibrate integrally. Therefore, at low frequencies, the double skin structure can be regarded as a single plate, and the laminated structure of the double skin structure, the sound absorbing material 14, and the interior panel 7 can be considered as a double wall structure (see FIG. 7).

[0033] FIG. 7 shows an equivalent rigid plate 2a' to replace the double skin structure. In such a double wall structure, as shown in FIG. 8, in a broad high frequency range including the high frequency resonance frequency frH, the transmission loss as an index of the sound insulation performance is improved as compared with the mass law. However, in the low frequency range, it is known that the transmission loss falls below the mass law near the low frequency resonance frequency frL on the contrary, due to the resonance phenomenon in which the equivalent rigid plate 2a' and the interior panel 7 serve as mass and the air layer (equivalent to the space 15) being a medium of the sound absorbing material 14 serves as a spring.

[0034] Here, when the thickness of the air layer is large (thick solid line in FIG. 8), since the low frequency resonance frequency frL shifts to the lower frequency side as compared with the case where the thickness of the air layer is small (dotted line in FIG. 8), transmission loss is improved on the higher frequency side with respect to the low frequency resonance frequency frL.

[0035] It should be noted that when the thickness of the air layer is increased, the high frequency resonance frequency frH also shifts to the low frequency side. However, in a configuration of a normal railway vehicle, the high frequency resonance frequency frH exists in a high frequency range of not less than 1 kHz, and in such a high frequency range, noise is sufficiently attenuated by the sound absorbing performance due to the sound absorbing material 14, the seat 11 in the vehicle interior space, and the like, so that the shift of the high frequency resonance frequency frH does not normally come to a problem.

[0036] Thus, in order to improve the sound insulation performance of the vehicle, it is effective to widen the space 15 between the roof structure 2a (2b) or side structure 3 (floor structure 4) being double skin structures and the interior panel 7 or top plate 8a and to increase the thickness of the sound absorbing material 14 inserted into the space 15.

[0037] However, the external dimensions of the vehicle body are restricted by a boundary line referred to as a vehicle gauge, and it is difficult to increase the external shape of the vehicle body beyond that. On the other hand, in order to widen the space 15, it is one idea to shift the interior panel 7 and the top plate 8a to the vehicle interior side.

[0038] However, according to this idea, since the vehicle interior space is reduced, it is difficult to secure the ceiling height and the load shelf space required to maintain passenger comfort. In addition, when the space between the side structure 3 and the interior panel 7 is widened, it is difficult to secure a necessary seat width and a necessary passage width.

[0039] Thus, the present inventors performed an element test and analysis simulating the laminated structure of the double skin structure, the sound absorbing material 14, and the interior panel 7, and studied the conditions under which the effect of improving the transmission loss is significantly exhibited by drilling a hole in the inner plate 2b2 of the double skin structure.

[0040] According to the study results, in FIG. 7, it has been found that providing a hole in a region where an interval between the inner plate 2b2 of the double skin structure and the interior panel 7, that is, the thickness dimension t of the space 15 is approximately three times or less with respect to the structure thickness L (also simply referred to as the thickness) of the double skin structure ($t \leq 3L$) exhibits a significant effect. It should be noted that it is more preferable that $t \leq 2L$.

[0041] As shown in FIGS. 3 and 4, the railway vehicle of the present embodiment is provided with the air conditioner 5 or the current collector 6 on the roof, and therefore has a large dimensional constraint in the ceiling height direction, so that there is an actual situation that the thickness of the sound absorbing material 14 cannot be sufficiently secured. Thus, in a situation where the sound absorbing material 14 has to be thin, it is particularly effective to provide a hole 16.

[0042] Therefore, in the railway vehicle of the present embodiment, making holes in the inner plate 2a2 or 2b2 of the roof structure 2a or 2b increases the transmission loss and improves the sound insulation performance, so that the transmission of aerodynamic noise generated by the air conditioner 5 or the current collector 6 on the roof into the vehicle interior is reduced.

<First embodiment>

[0043] FIG. 9 is a perspective view of a roof structure provided with holes in a face plate on the vehicle interior side, and FIG. 10 is a cross-sectional view illustrating a state in which a sound absorbing material and an interior panel are arranged on the vehicle interior side of a roof structure provided with holes in a face plate on the vehicle interior side.

[0044] The structure thickness L of the double skin structure of a general railway vehicle is often designed

to be about L = 30 mm to 70 mm. On the other hand, the interval between the roof structure 2b of the vehicle on which the air conditioner 5 or the current collector 6 is mounted and the interior panel 7, that is, the thickness t of the sound absorbing material can be often secured only with a thickness of approximately 70 mm or less although differing depending on the type and region of the vehicle.

[0045] Thus, a plurality of holes 16 penetrating the inner plate 2b2 along the X direction are drilled at positions between the connection portions between the face plate (inner plate) 2b2 on the vehicle interior side and the connection plates 2b3 in the double skin structure. As a result, the vehicle interior side cavity 17 surrounded by the inner plate 2b2 and the connection plates 2b3 of the double skin structure communicates with the space 15 through the holes 16, and the compressional wave of the sound wave transmitted through a double skin structure DS can also enter the vehicle interior side cavity 17.

[0046] In other words, providing the holes 16 increases the thickness t of the space 15 by the structure thickness L of the double skin structure DS, that is, the effect such that the thickness increases to (t + L) is obtained.

[0047] In particular, in a region where the thickness t of the space 15 cannot be sufficiently secured, and $t \leq 3L$ (preferably $t \leq 2L$) is required, since the effect that the thickness t of the space 15 is increased to 1.3 times or more (preferably 1.5 times or more) can be obtained, a significant effect of improving sound insulation performance is obtained. In other words, even if the sound absorbing material becomes thinner in the region of the double skin structure where $t \leq 3L$ (preferably $t \leq 2L$), a sufficient effect of improving sound insulation performance can be obtained by providing the holes 16.

[0048] Communicating the space 15 with the vehicle interior side cavity 17 inside the double skin structure DS causes the mechanism of improving sound insulation performance in the present embodiment to exert the same effect as when the thickness of the space 15 is increased. Therefore, drilling only a minimum necessary number of holes with as large diameter as possible is more excellent in sound insulation performance than drilling a large number of holes with small diameter, and is also preferable from the viewpoint of preventing an increase in the number of manufacturing steps due to hole drilling.

[0049] However, in order to prevent the decrease in strength of the double skin structure DS due to drilling, it is preferable that the inner diameter d of the hole 16 be approximately in a range where $(P/5) \leq d \leq (4P/5)$ with respect to the interval of the connection portions between the inner plate 2b2 and the connection plates 2b3 of the double skin structure DS (pitch P in the Y direction).

[0050] In addition, in order to minimize a decrease in strength due to drilling in the double skin structure, it is preferable to arrange the holes 16 so that the distance between the holes 16 is as large as possible. Therefore, in the present first embodiment, with respect to each hole 16 arranged in a row at equal pitch along the vehicle interior side cavity 17 (in the X direction), the position of each hole 16 arranged in a row at equal pitch adjacent thereto is structured to shift in the X direction by a half pitch to form a staggered arrangement (see FIG. 9).

[0051] With the above-described configuration, drilling the holes 16 in the region of the double skin structure where the thickness of the space 15 cannot be secured to be large allows the structure thickness L of the double skin structure to be also used as a part of the thickness of the space 15. Thus, it is possible to provide a railway vehicle capable of preventing a decrease in strength and an increase in the number of machining steps due to drilling holes in the inner plate of the double skin structure, the railway vehicle having excellent sound insulation effect.

<Second embodiment>

[0052] The second embodiment has a configuration where the hole 16 in the face plate (inner plate) 2b2 on the vehicle interior side is prevented from being blocked by double-sided tape or the like when the sound absorbing material 14 is fixed to the inner plate and is secured to communicate between the vehicle interior side cavity 17 and the space 15, so that an excellent sound insulation effect can be obtained.

[0053] FIG. 11 is a perspective view of a roof structure provided with a hole in a region including a plate thickness portion of a face plate on the vehicle interior side, and FIG. 12 is a cross-sectional view illustrating a state in which a sound absorbing material and an interior panel are arranged on the vehicle interior side of a roof structure provided with a hole in a region including a plate thickness portion of a face plate on the vehicle interior side.

[0054] The double skin structure such as the roof structure 2a (2b) or the side structure 3 of the second embodiment includes a protrusion 18 that increases the thickness by protruding toward the vehicle interior side opposite to the vehicle interior side cavity 17 and is formed continuously along the X direction for each region of the inner plate 2b2 partitioned by the inner plate 2b2 and a pair of connection plates 2b3.

[0055] Since the protrusion 18 is provided at the center in the Y direction between the connection portions between the inner plate 2b2 and the connection plates 2b3, and continuously extends along the X direction, the protrusion 18 can be formed by extrusion molding integrally with the double skin structure.

[0056] Furthermore, the inner plate 2b2 has a plurality of holes 16 provided discretely at an equal pitch on the protrusion 18 along the extrusion direction (X direction) of the protrusion 18. Since the inner diameter d of the hole 16 is larger than the width dimension W of the protrusion 18 in the Y direction, a part of the hole 16 protrudes from the protrusion 18. It is preferable that the central axis of each hole 16 intersects the center line of the projection 18.

[0057] The sound absorbing material 14 is applied with an adhesive (or pasted with a double-sided tape or the like) on one surface thereof and bonded to the inner plate 2b2 of the double skin structure, and then the interior panel 7 is attached to the other surface.

[0058] Assuming that the sound absorbing material 14 is bonded or pasted to the inner plate 2b2 having no protrusion 18, there are possibilities that the hole 16 is closed by an adhesive weak in air permeability, double-sided tape, or the like, the effect of using the vehicle interior side cavity 17 is not sufficiently exhibited, and the sound insulation performance cannot be improved.

[0059] On the other hand, in the present embodiment, providing the inner plate 2b2 with the protrusion 18 forms a gap 19 so as to spread from the surface on the vehicle interior side of the inner plate 2b2 to the end potion of the vertical surface 18a in the height direction of the protrusion 18. Since no adhesive or the like is applied to the gap 19 and a part of the hole 16 protruding from the protrusion 18 is not blocked, the compressional wave of the sound wave propagated into the space 15 can enter the vehicle interior side cavity 17 through the gap 19 and a part of the hole 16 along the sound wave entry path 21. Thus, the effect of improving the sound insulation performance can be obtained.

[0060] In a tunnel or the like, a force is applied in a direction in which the structure of the railway vehicle expands and contracts in a cross section due to an airtight load generated by internal and external pressure difference of the vehicle. Therefore, when an airtight load acts on the railway vehicle structure 1a (1b), as indicated by arrow 22, a tensile/compressive load acts in a direction intersecting the X direction on the double skin structure DS such as the roof structure 2a (2b) and the side structure 3 constituting the railway vehicle structure 1a (1b).

[0061] For this reason, it is considered that a stress is most concentrated particularly on the end portion in the vehicle longitudinal direction (direction vertical to the paper surface in the sectional view) among the peripheral portions of the hole 16 of the inner plate 2b2 of the double skin structure. However, according to the configuration of the second embodiment, since the protrusion 18 having a large plate thickness is provided near the hole 16, even when the hole 16 is provided, the fatigue durability of the double skin structure can be improved.

[0062] Furthermore, the provision of the protrusion 18 has an effect that the hole 16 can be easily positioned at the time of construction. In the double skin structure where the protrusion 18 is not provided, since it is difficult to understand the position of the connection plate 2b3 and the vehicle interior side cavity 17 only by viewing from the inner plate 2b2 side, it is difficult to machine the hole 16 without interfering with the connection plate 2b3 and the vehicle interior side cavity 17. However, the provision of the protrusion 18 facilitates the positioning of the hole 16 by using the protrusion 18 as a marker, thereby improving the workability of drilling.

[0063] According to the above configuration, providing the protrusion 18 in the double skin structure makes it possible to provide a railway vehicle which can avoid a decrease in sound insulation performance due to the hole 16 being closed when the sound absorbing material 14 is bonded to the inner plate 2b2 and which can improve the fatigue durability and workability of the double skin structure.

<Third embodiment>

[0064] FIG. 13 is a perspective view of a roof structure provided with a hole at a joint portion between a face plate on the vehicle interior side and a connection plate for connecting the face plates inside and outside the vehicle, and FIG. 14 is an enlarged cross-sectional view of a roof structure including a hole at a joint portion between a face plate on the vehicle interior side and a connection plate for connecting the face plates inside and outside the vehicle.

[0065] The configuration of the third embodiment is provided with a hole 16 at a connection portion between the inner plate 2b2 of a double skin structure and the connection plate 2b3 connected to the inner plate 2b2. The hole 16 is provided near the intersection point 23 of the virtual center extension line (surface) of one connection plate 2b3 and the virtual center extension line (surface) of the other connection plate 2b3 adjacent to each other, shown by the dotted line in FIG. 14, and near the inner plate 2b2; and is preferably provided so that the central axis of the hole 16 passes through the intersection point 23.

[0066] Since the diameter of the hole 16 is larger than the connection portion of the connection plates 2b3, one hole 16 causes the space 15 (sound absorbing material 14) to communicate with the two vehicle interior side cavities 17 and one vehicle exterior side cavity 20 sandwiched between the two vehicle interior side cavities 17.

[0067] With this configuration, providing one hole 16 allows the three cavities (17, 20) to be used as a common space, so that even if the number of holes 16 is reduced, a sound insulation effect similar to that of the above embodiment can be obtained. Thus, the number of machining steps of the hole 16 can be reduced.

[0068] Further, the top portion where a pair of adjacent connection plates 2b3 and the inner plate 2b2 intersect is a region having relatively high strength. Therefore, even when the holes 16 are provided, a decrease in strength of the double skin structure can be prevented.

[0069] With the above configuration, since the space 15 and the three cavities (17, 20) can be communicated via one hole 16, forming holes 16 at every other connection portion can reduce the number thereof, for example. Thus, it is possible to provide a railway vehicle capable of preventing a decrease in strength and an increase in the number of machining steps due to drilling holes in the inner plate of the double skin structure, the railway vehicle having excellent sound insulation effect.

<Fourth embodiment>

[0070] FIG. 15 is a perspective view of a roof structure provided with holes only in the face plate near the curtain rail structure of the vehicle interior side face plate having the curtain rail structure, and FIG. 16 is a cross-sectional view illustrating a state in which a sound absorbing material and an interior panel are arranged on the vehicle interior side of a roof structure provided with holes only in the face plate near the curtain rail structure of the vehicle interior side face plate having the curtain rail structure.

[0071] The double skin structure integrally includes a curtain rail structure 13 for fixing the interior panel 7 and for fixing a bundle of the wiring cables as a part of the extruded hollow shape material. The curtain rail structure 13 is provided so as to extend in the X direction near or opposite to a connection portion between the pair of connection plates 2b3 and the inner plate 2b2. In addition to that the connection portion originally has high strength, further including the curtain rail structure 13 further increases the strength in the vicinity thereof.

[0072] In the fourth embodiment, the inner plate 2b2 near the curtain rail structure 13 is provided with holes 16 discretely at an equal pitch along the X direction. Providing the holes 16 near the curtain rail structure 13 having high strength allows the curtain rail structure 13 to perform a function alternative to that of the protrusion 18 as described in the second embodiment.

[0073] Furthermore, attaching a drill or the like to a jig (not shown) which has a predetermined span in the Y direction from the curtain rail structure 13 and slides along the curtain rail structure 13 can also perform a drilling operation on the inner plate 2b2. Thus, a plurality of holes 16 can be highly precisely formed along the curtain rail structure 13 by a simple operation.

[0074] With the above configuration, even when holes 16 are drilled in the inner plate 2b2, providing the curtain rail structure 13 in the double skin structure makes it possible to provide a railway vehicle which can secure strength of the double skin structure and reduce the number of machining steps, and which has excellent sound insulation effect.

[0075] It should be noted that in the first to fourth embodiments of the present invention, the configuration and effects of the present invention have been described by taking a railroad vehicle including an air conditioner or a current collector on a roof as an example. However, the same applies to the side structure 3 and the floor structure 4 shown in FIGS. 1 and 2, and the present invention can be applied to the region where restriction of dimensions is large and the thickness of the space between the double skin structure and the interior panel cannot be sufficiently secured based on exactly the same principle as described in the first to fourth embodiments.

[0076] In addition, in the embodiments of the present invention, the case where the cross-sectional shape of the double skin structure is a triangular truss structure including the outer plate 2b1 or the inner plate 2b2 and the pair of connection plates 2b3 has been described as an example. However, even when the cross-sectional shape of the double skin structure is, for example, a square structure, the present invention can be applied based on the same principle as described in the first to fourth embodiments of the present invention as long as it is a double skin structure including an outer plate, an inner plate, a vertical rib, and a cavity surrounded by the outer plate, the inner plate, and the vertical rib.

[0077] It should be noted that the present invention is not limited to the embodiments described above, and includes various modifications. For example, the above-described embodiments are described in detail for easy understanding of the present invention, and are not necessarily limited to those including all the configurations described. In addition, a part of the configuration of one embodiment can be replaced with the configuration of another embodiment, and the configuration of another embodiment can be added to the configuration of one embodiment. In addition, it is also possible to add, delete, and replace another configuration with respect to a part of the configuration in each of the embodiments.

Reference Signs List

[0078]

1a, 1b	railroad vehicle structure,
2a, 2b	roof structure,
2a1, 2b1	outer plate,
2a2, 2b2	inner plate,
2a3,2b3	connection plate,
3	side structure,
4	floor structure,
5	air conditioner,
6	current collector,
7	interior panel,
8	air-conditioning duct,
8a	top plate of air-conditioning duct,
8b	side surface of air-conditioning duct,
8c	opening on side surface of air-conditioning duct,
10	floor plate,
11	seat,
12	load shelf,
13	curtain rail structure,
14	sound absorbing material,
15	space,
16	hole,
17	vehicle interior side cavity,
18	protrusion (part with large plate thickness),
18a	vertical plane,
19	gap,
20	vehicle exterior side cavity,
21	sound entry path,
22	direction in which airtight load acts,
23	intersection point,

L structure thickness of structure,
t interval between sound absorbing material and interior panel

Claims

1. A rail vehicle including:

a double skin structure including:
a vehicle interior side face plate,
a vehicle exterior side face plate, and
a connection plate configured to connect the vehicle interior side face plate and the vehicle exterior side face plate,
a sound absorbing material provided on the vehicle interior side face plate, and
an interior material configured to cover the sound absorbing material,
the rail vehicle comprising a plurality of holes penetrating the vehicle interior side face plate,
wherein an interval t between the vehicle interior side face plate and the interior material is not more than three times a thickness dimension L of the double skin structure.

2. The rail vehicle according to claim 1, wherein each of the holes is formed in the vehicle interior side face plate so as to communicate with a vehicle interior side cavity partitioned by a pair of the connection plates and the vehicle interior side face plate.

3. The rail vehicle according to claim 1,

wherein the vehicle interior side face plate includes a protrusion which protrudes from the vehicle interior side face plate toward the sound absorbing material side at a position opposing to the vehicle interior side cavity partitioned by a pair of the connection plates, and which is continuously provided along a longitudinal direction of the rail vehicle, and
wherein at least a part of each of the holes is provided on the protrusion.

4. The rail vehicle according to claim 3, wherein an inner diameter of each of the holes is larger than a width dimension of the protrusion.

5. The rail vehicle according to claim 1, wherein forming each of the holes at a joint portion between the vehicle interior side face plate and a pair of the connection plates connected to the vehicle interior side face plate causes each of the holes to communicate with a vehicle exterior side cavity partitioned by the vehicle exterior side face plate and the pair of connection plates, a vehicle interior side cavity partitioned by the vehicle interior side face plate and the pair of connection plates, and a space between the vehicle interior side face plate including the sound absorbing material and the interior material.

6. The rail vehicle according to claim 1,

further comprising a curtain rail structure on a surface on a side of the sound absorbing material of the vehicle interior side face plate, and
wherein the vehicle interior side face plate has the holes near the curtain rail structure.

7. The rail vehicle according to any one of claims 1 to 6, wherein the double skin structure is used for a roof structure constituting the rail vehicle, and an air conditioner or a current collector is mounted on the roof structure.

FIG. 1

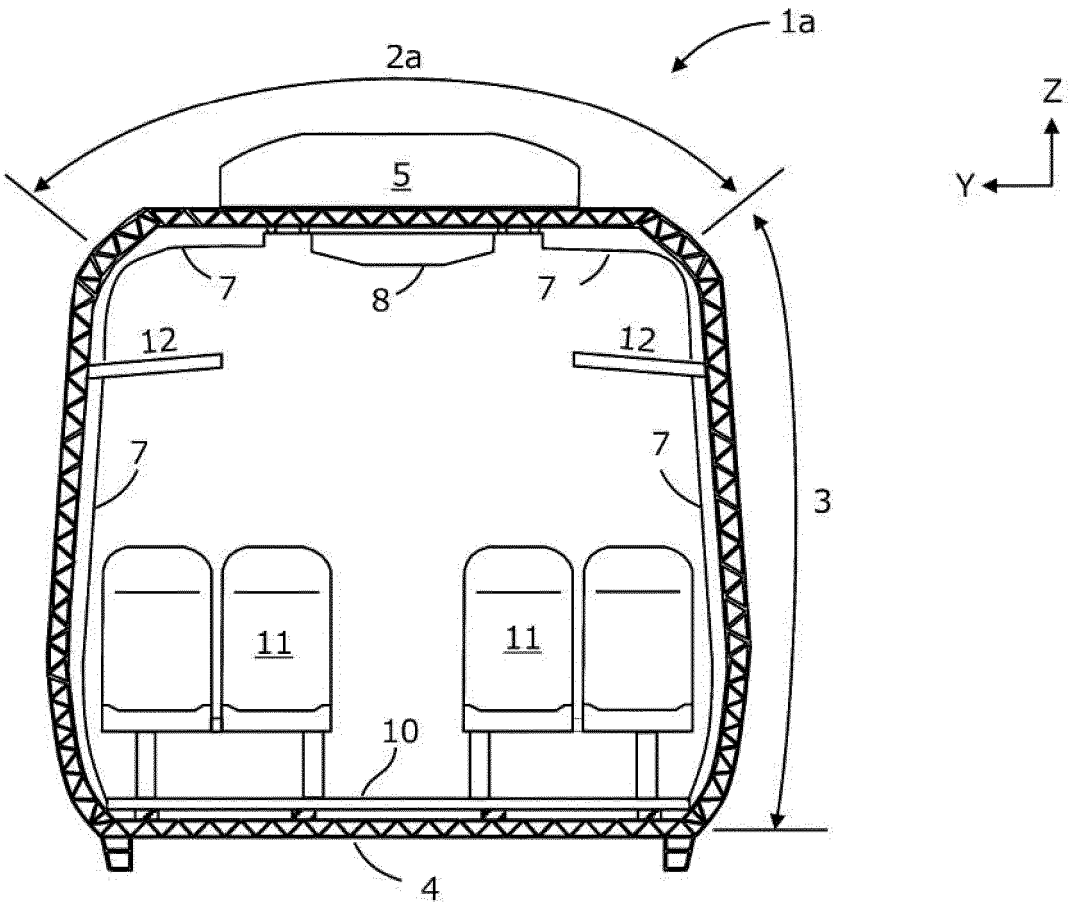
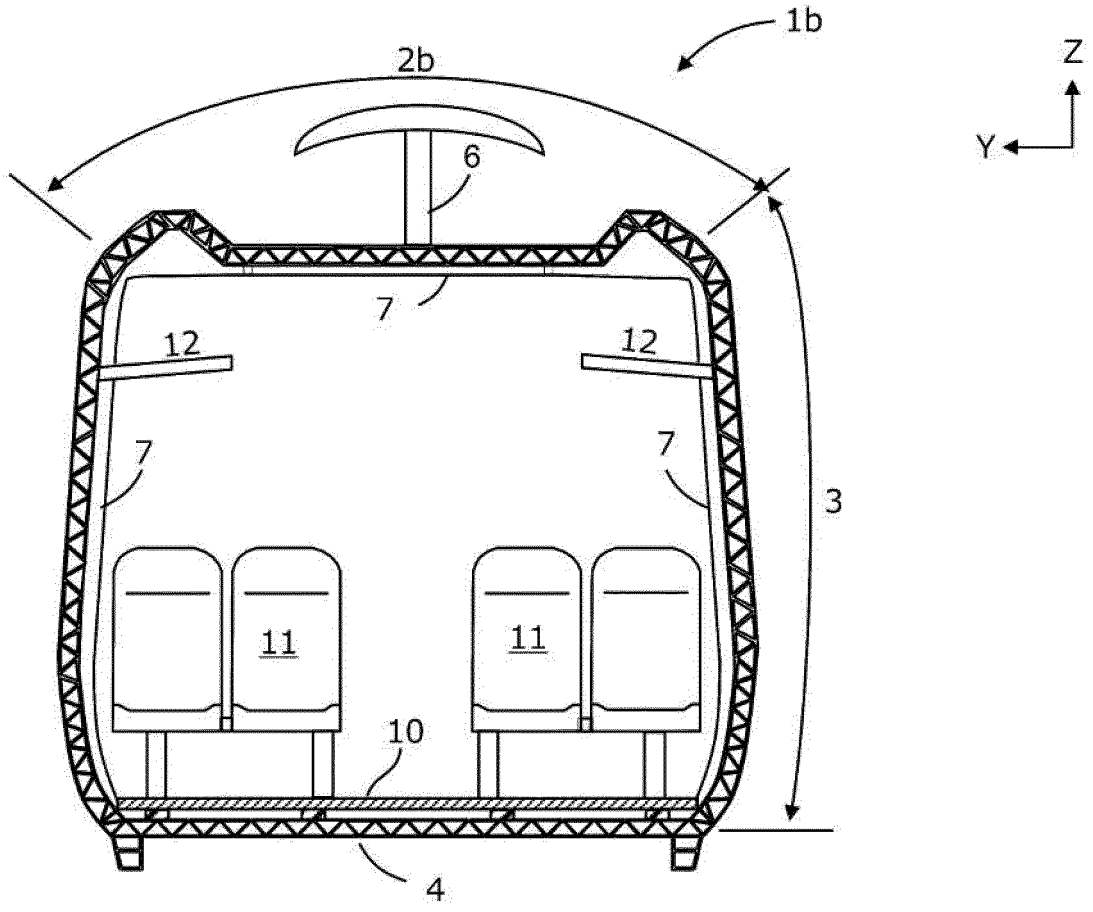


FIG. 2



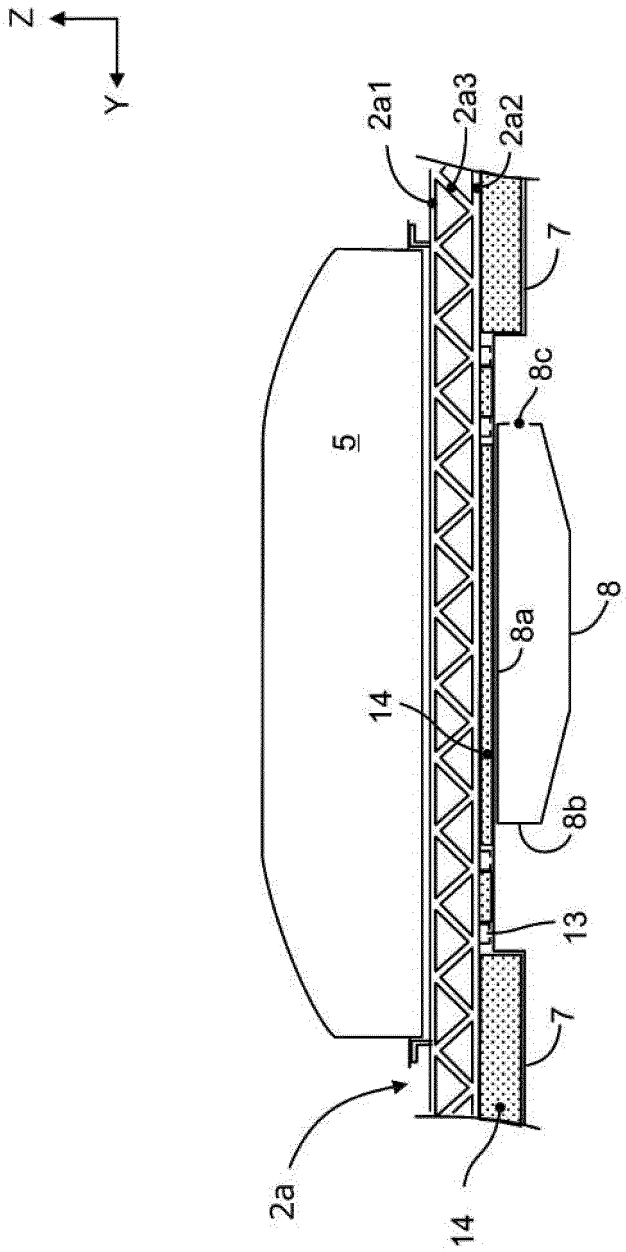


FIG. 3

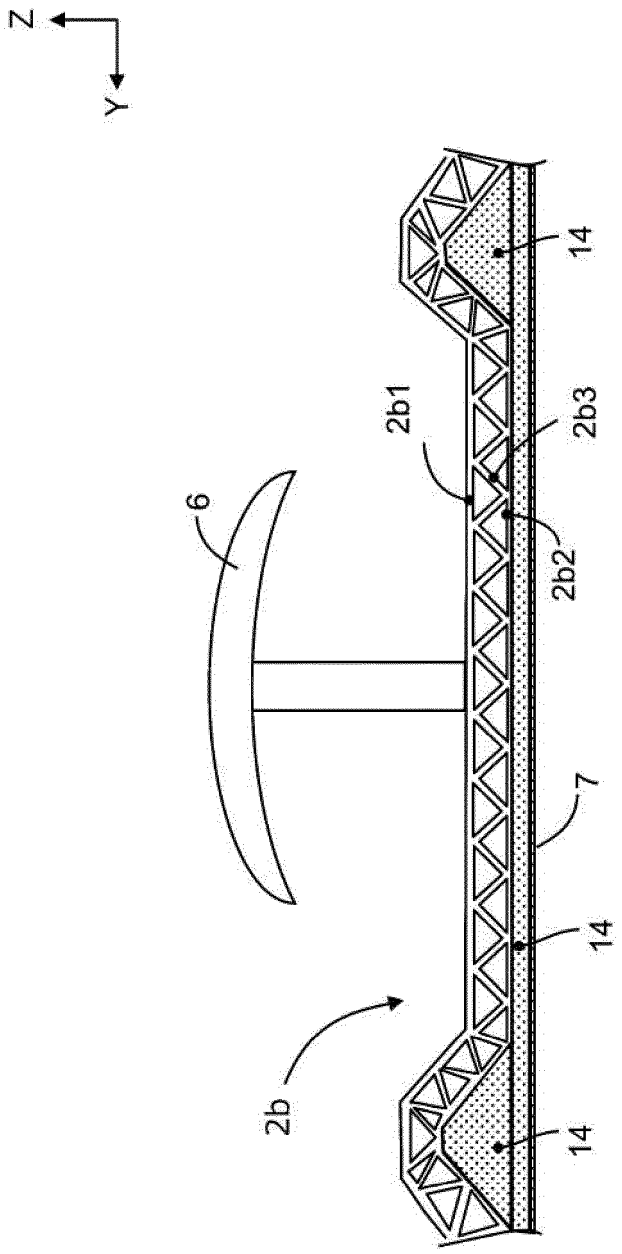


FIG. 4

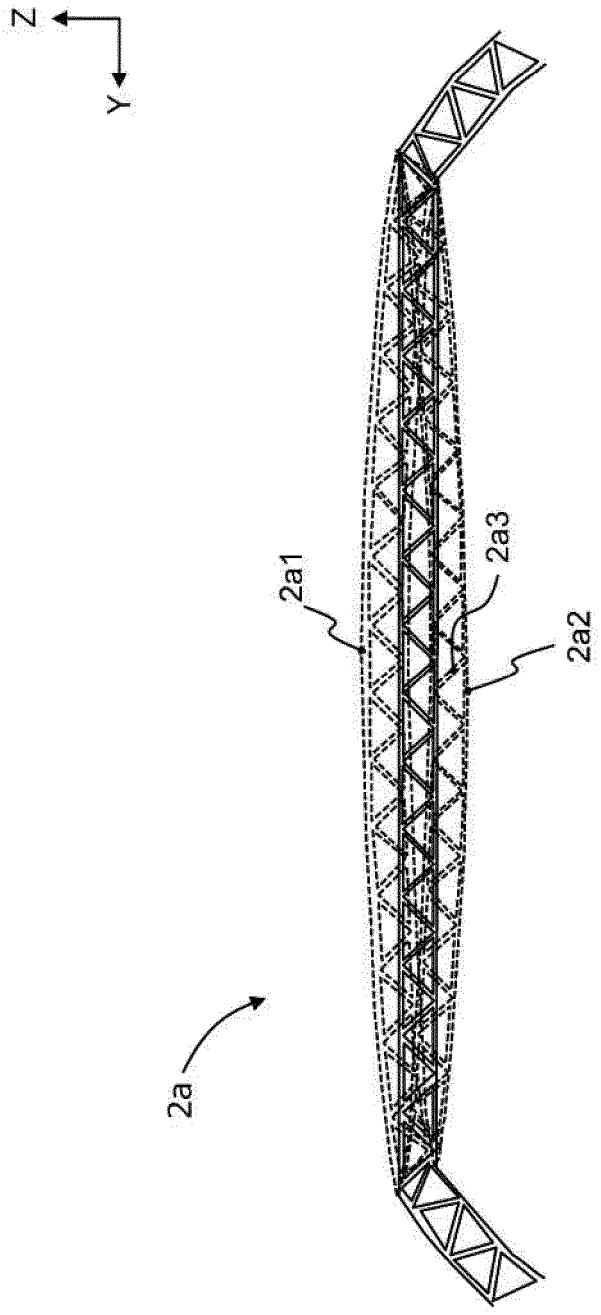


FIG. 5

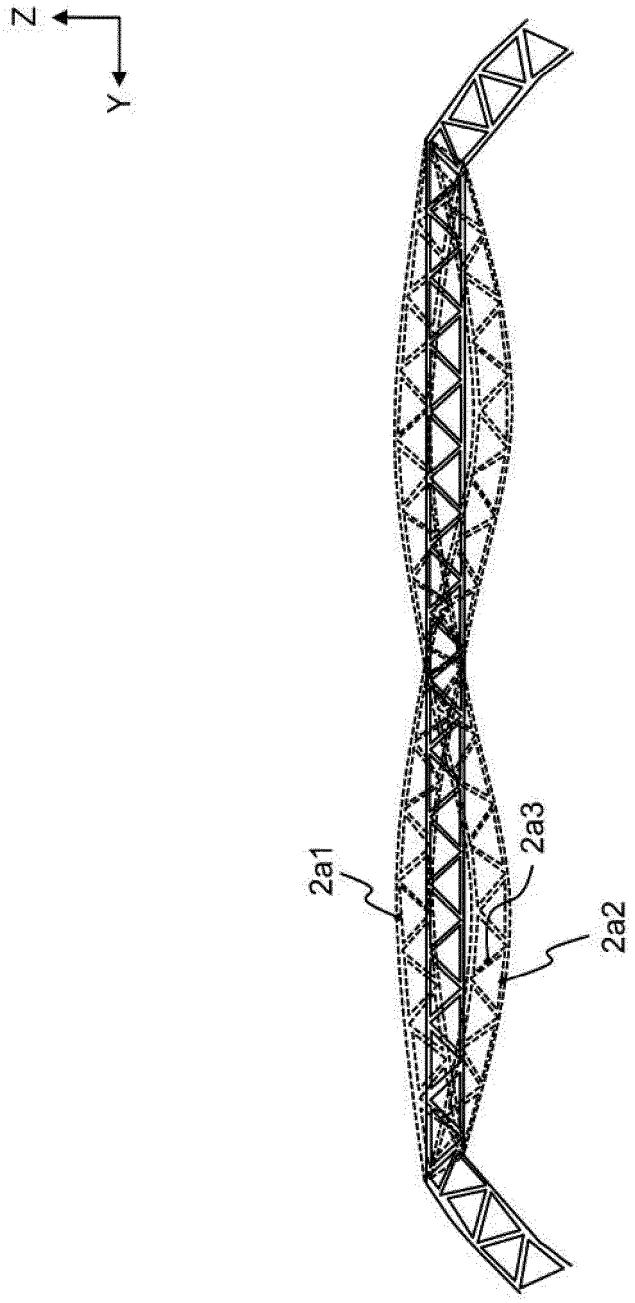


FIG. 6

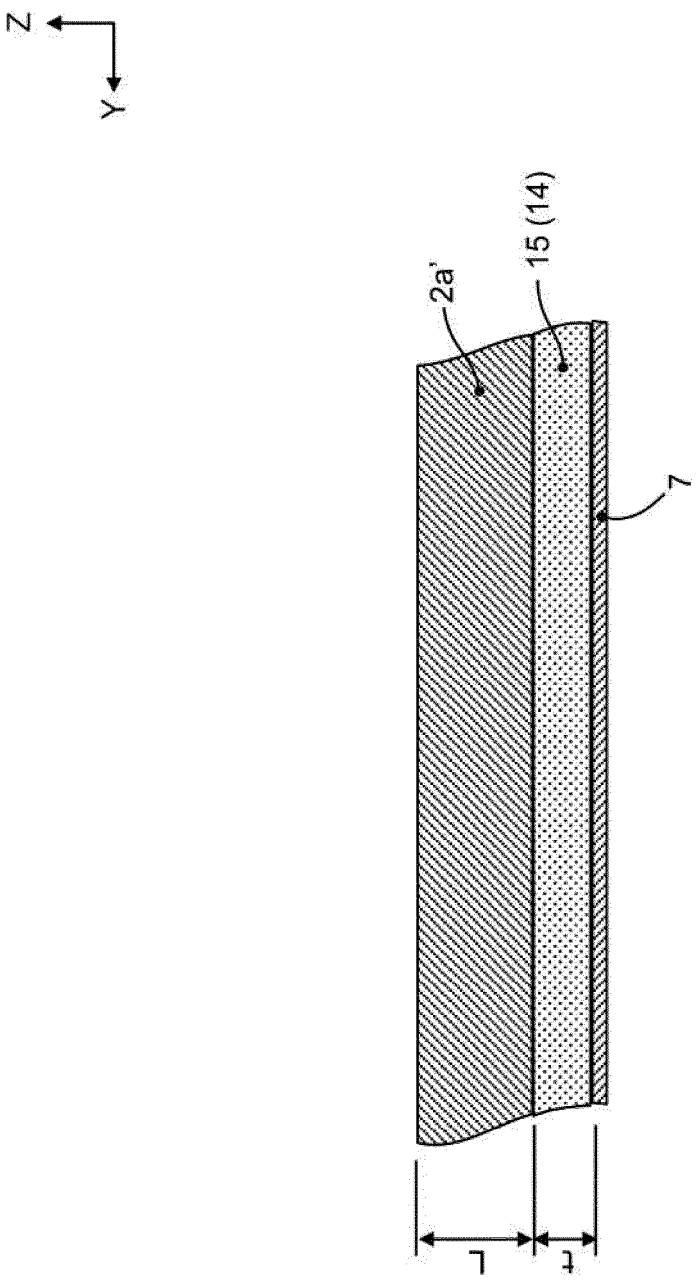
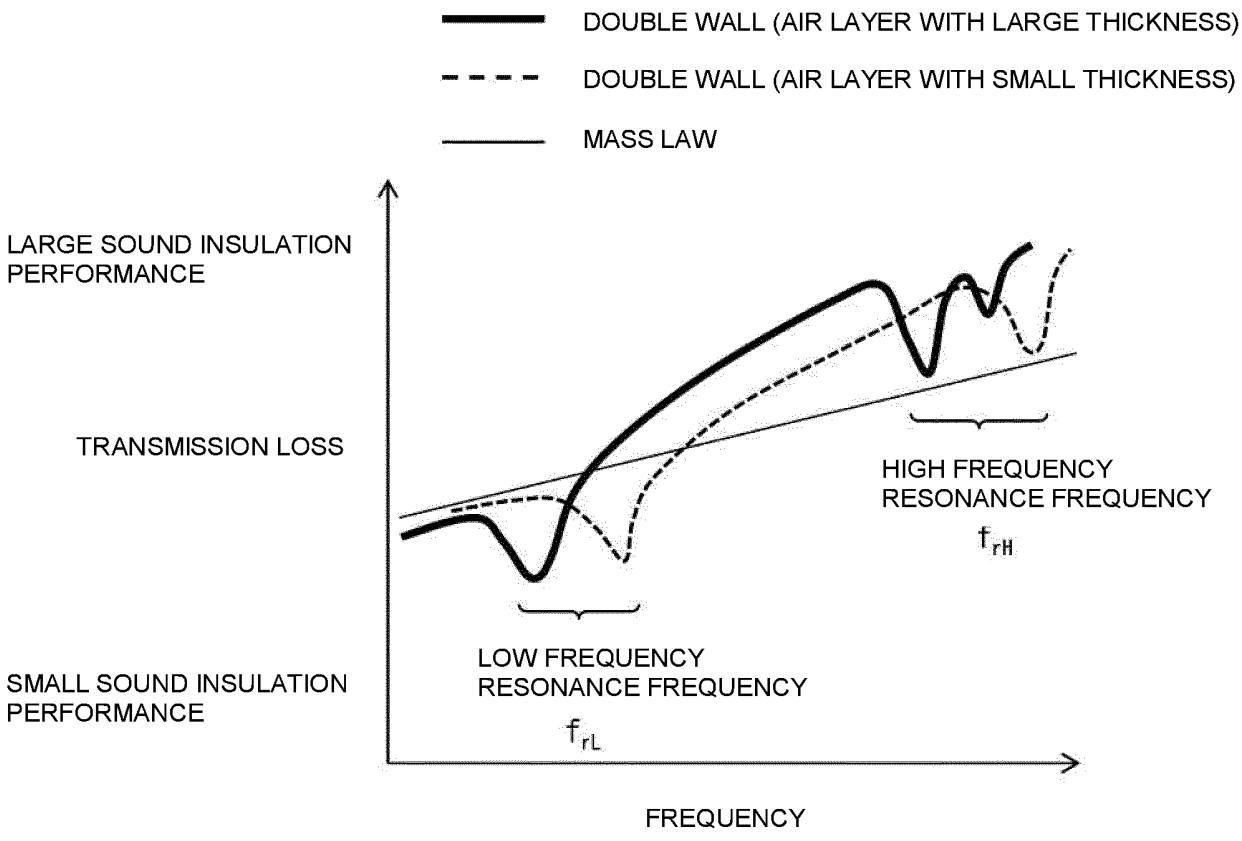


FIG. 7

FIG. 8


DOUBLE WALL (AIR LAYER WITH LARGE THICKNESS)
DOUBLE WALL (AIR LAYER WITH SMALL THICKNESS)
MASS LAW
LARGE SOUND INSULATION PERFORMANCE
TRANSMISSION LOSS
SMALL SOUND INSULATION PERFORMANCE
HIGH FREQUENCY RESONANCE FREQUENCY
f_{rH}
LOW FREQUENCY RESONANCE FREQUENCY
f_{rL}
FREQUENCY

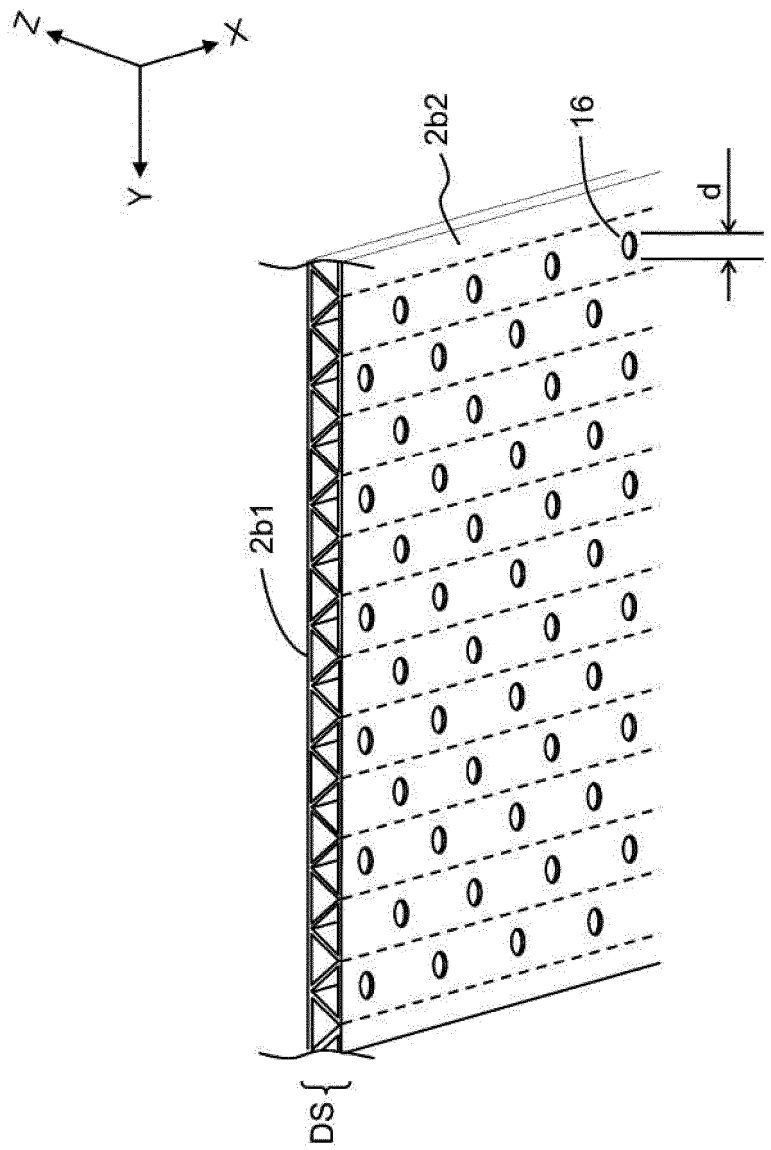


FIG. 9

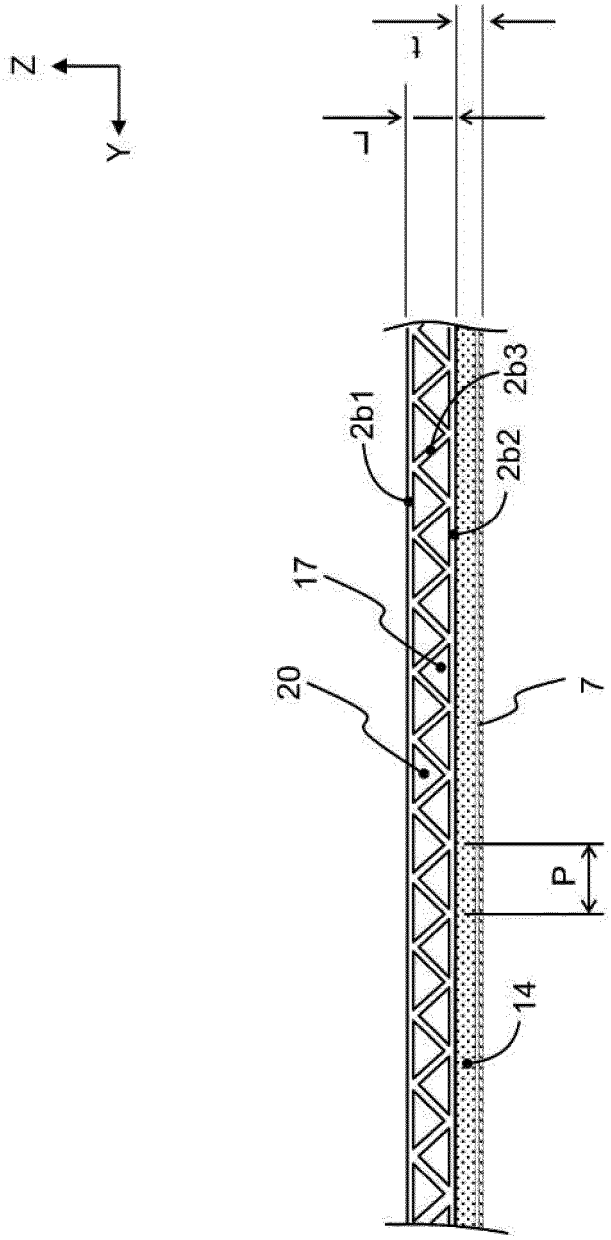


FIG. 10

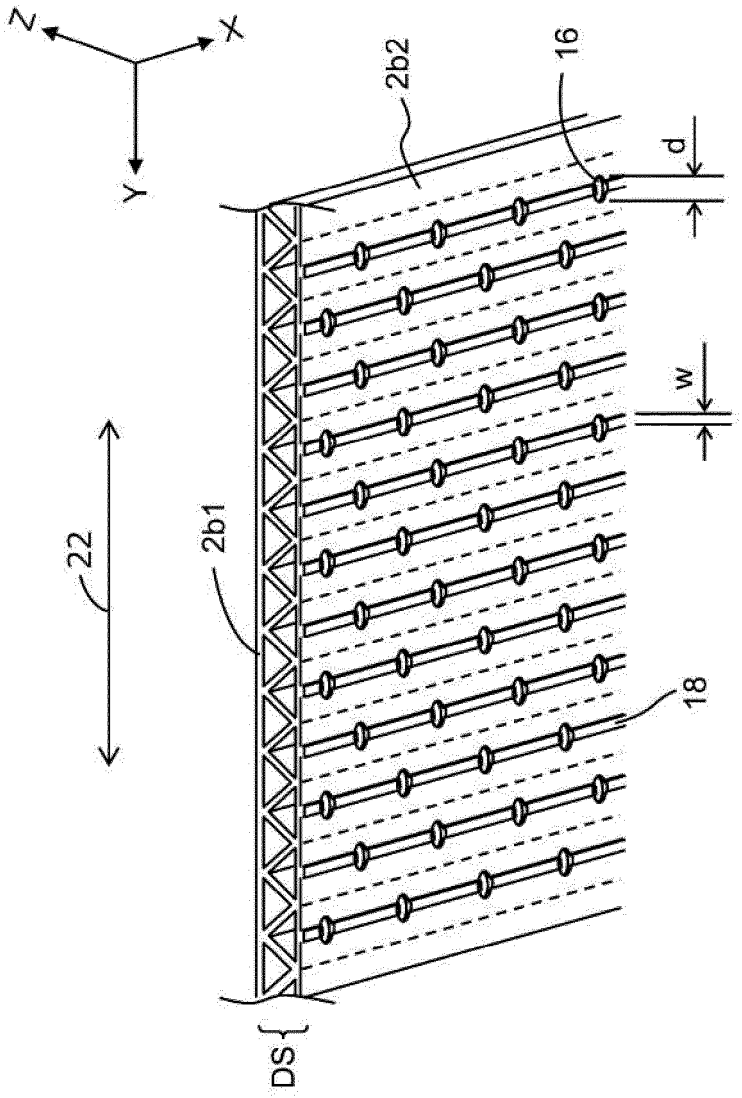


FIG. 11

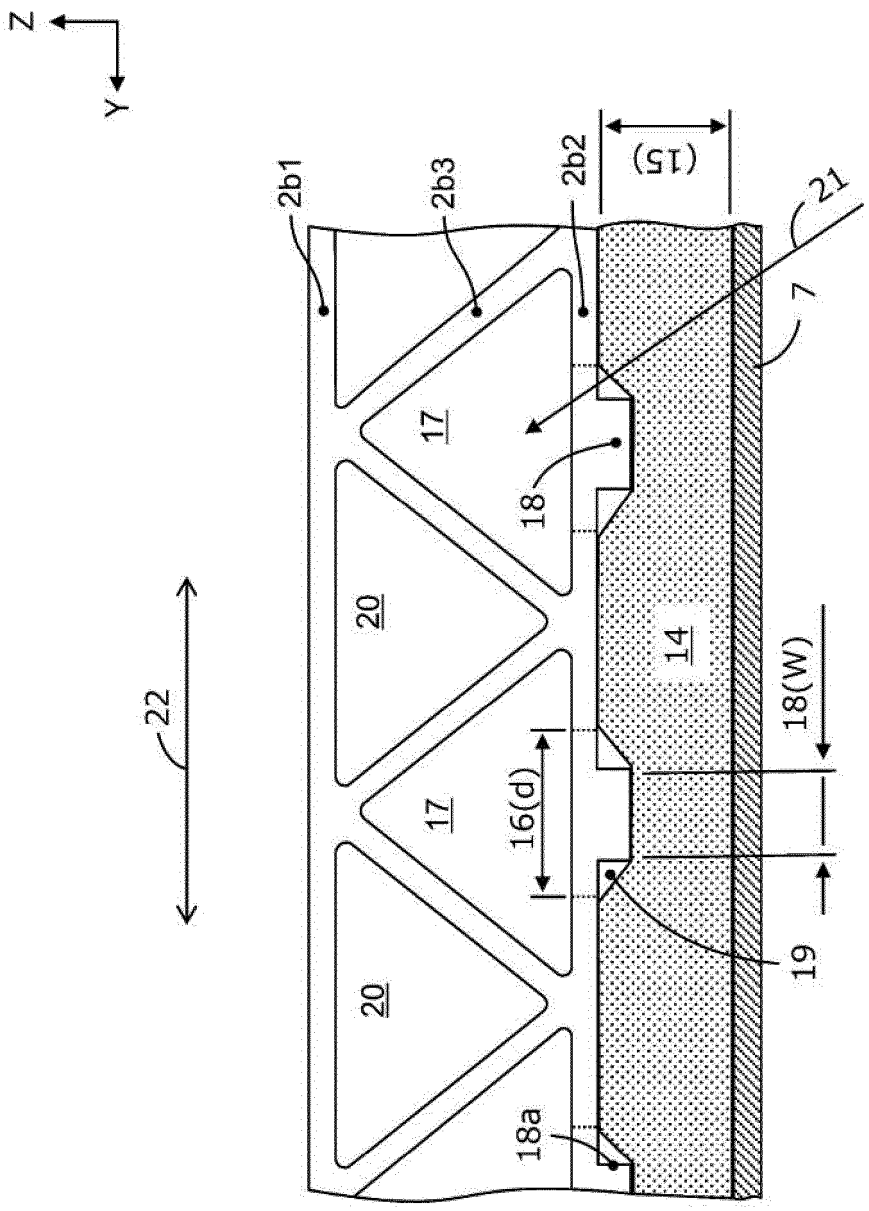


FIG. 12

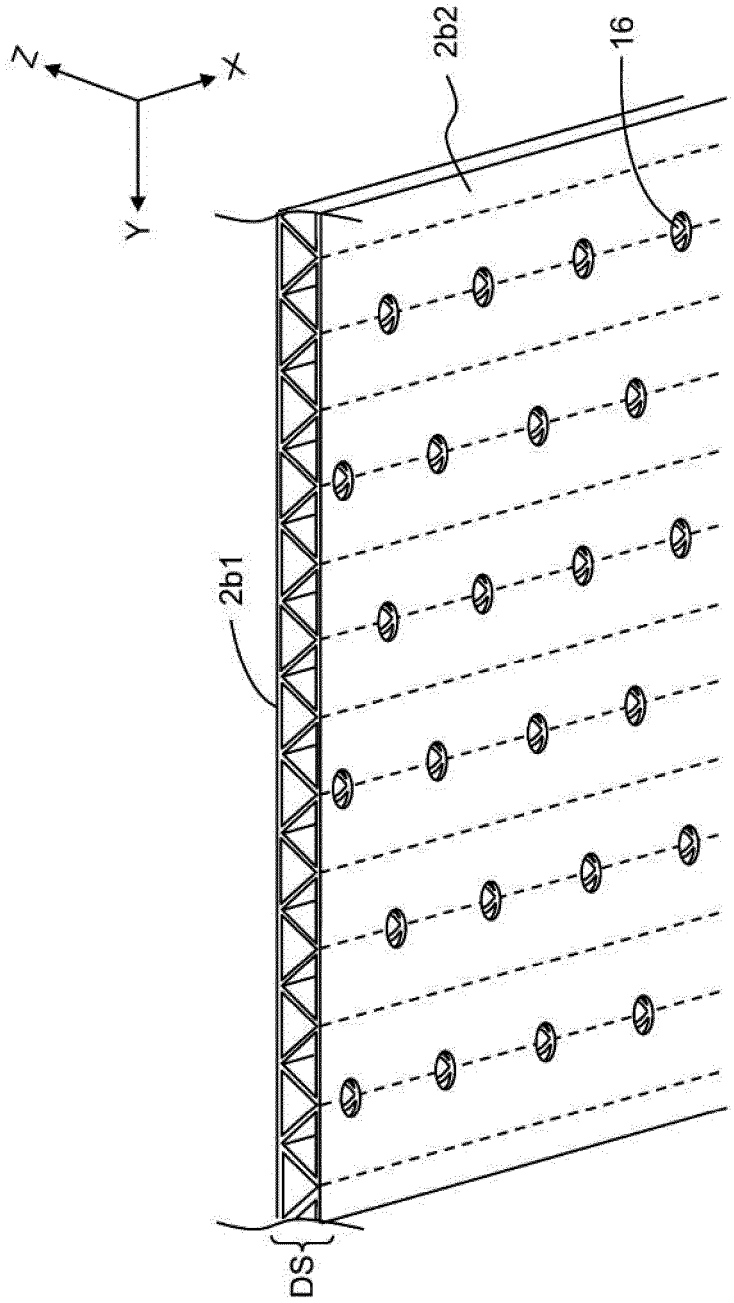


FIG. 13

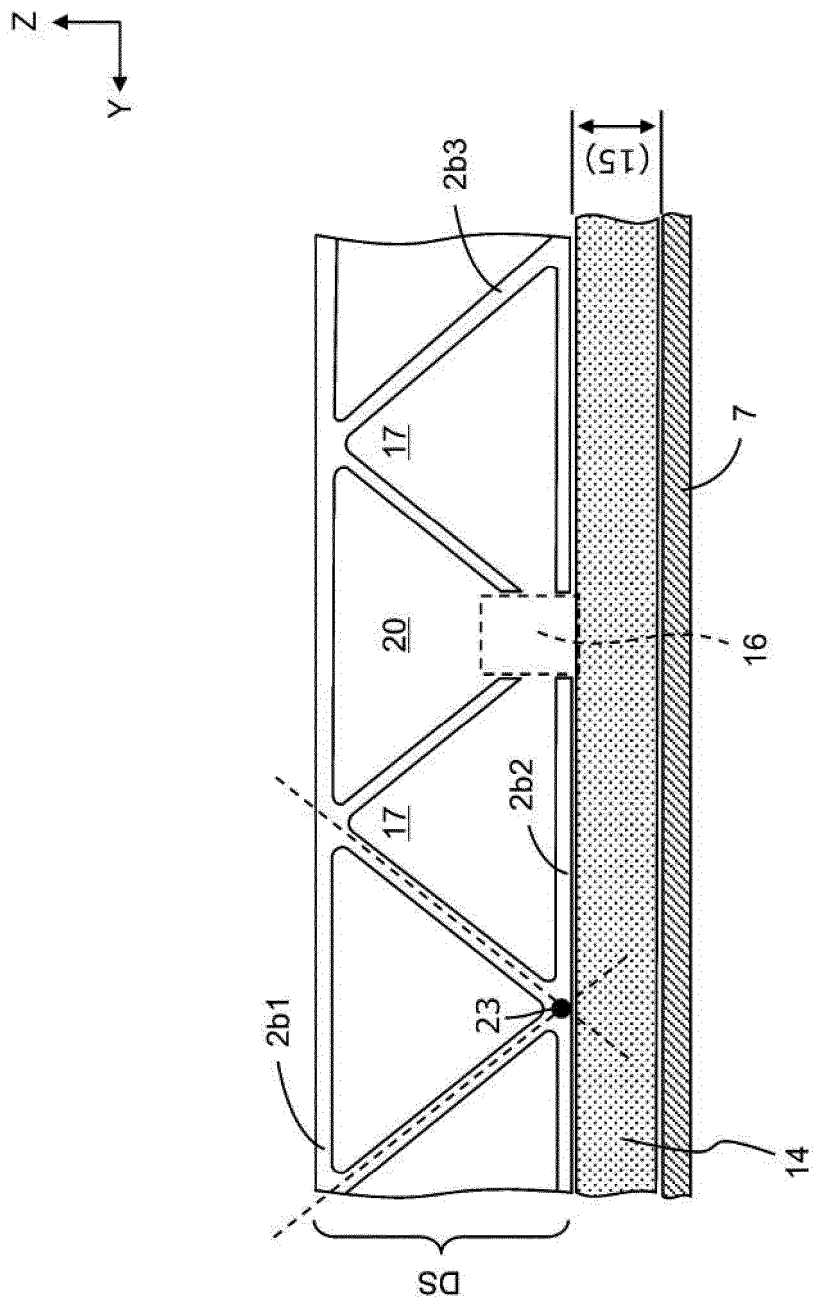
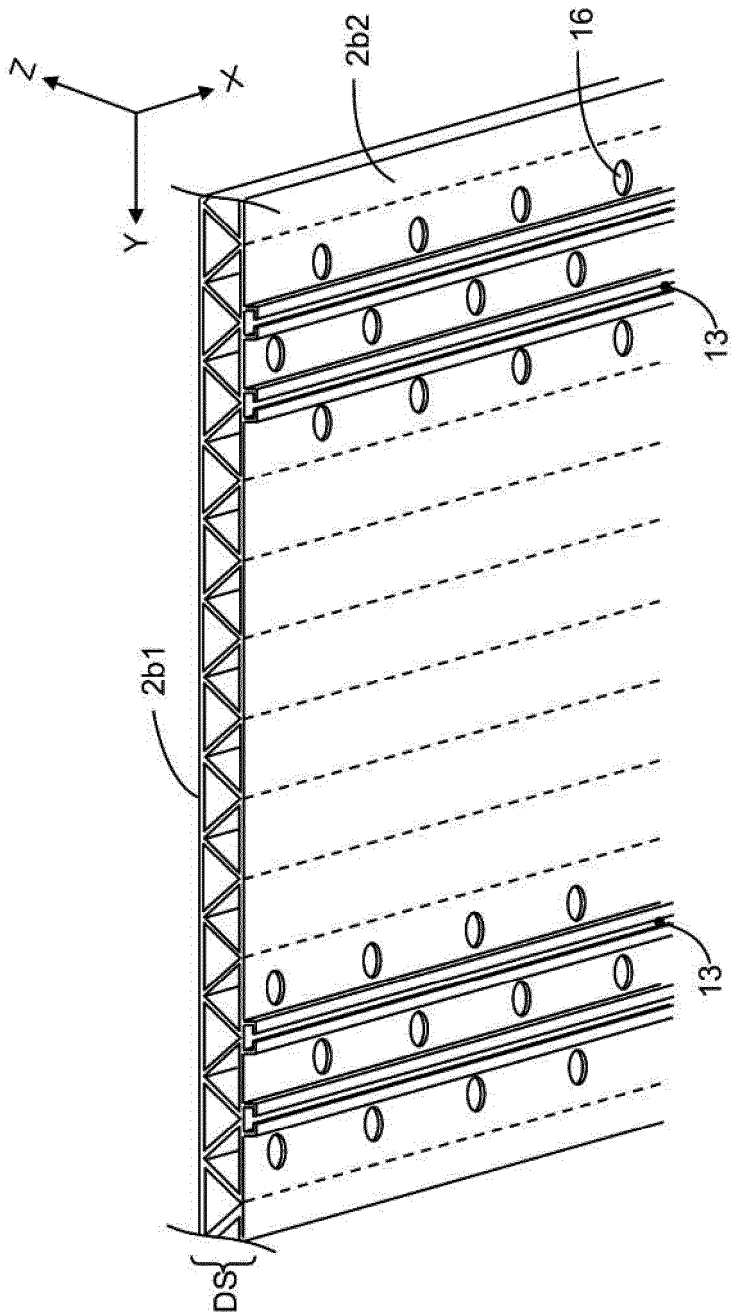


FIG. 14

FIG. 15



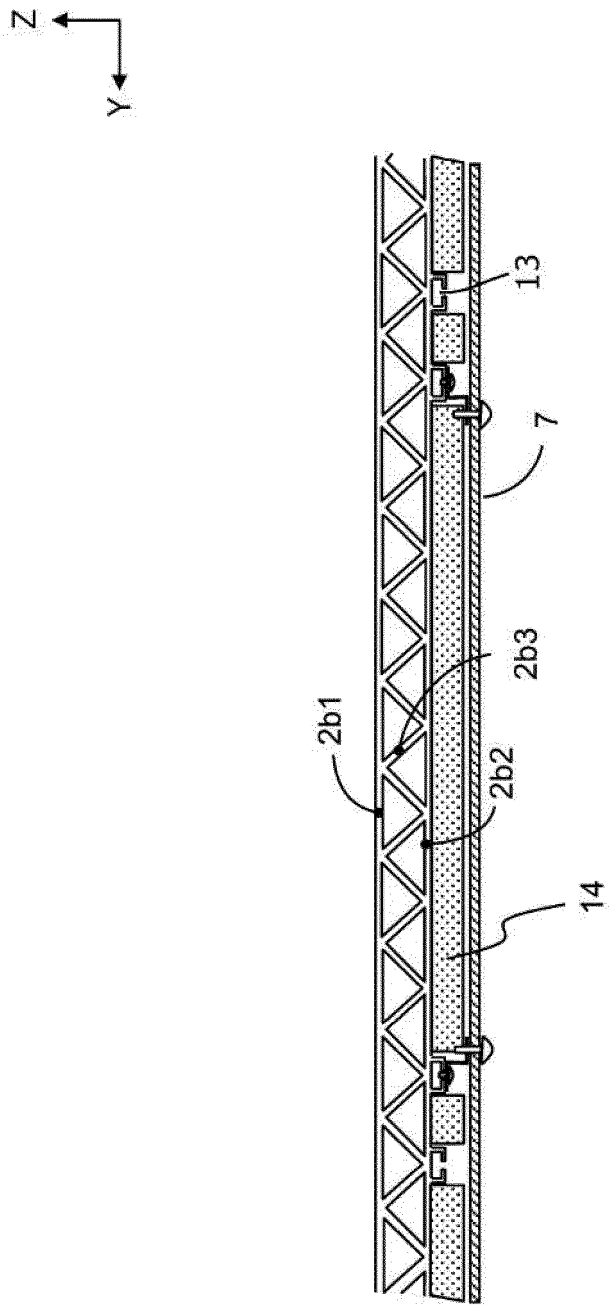


FIG. 16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/006227

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. B61D49/00(2006.01)i, B61D17/12(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)
Int.Cl. B61D49/00, B61D17/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2019
Registered utility model specifications of Japan 1996-2019
Published registered utility model applications of Japan 1994-2019

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 Y A	JP 2017-105228 A (HITACHI, LTD.) 15 June 2017, paragraphs [0012]-[0016], fig. 1-4 (Family: none)	1-2, 7 6 3-5
Y A	JP 2010-269757 A (HITACHI, LTD.) 02 December 2010, paragraph [0021], fig. 3 (Family: none)	6 1-5, 7

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

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"P" document published prior to the international filing date but later than the priority date claimed
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"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
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26.04.2019	21.05.2019
Name and mailing address of the ISA/ Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/006227

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 2007-223340 A (HITACHI, LTD.) 06 September 2007 & US 2006/0175126 A1 & EP 1690770 A1 & CA 2535294 A1 & KR 10-2006-0090607 A & CN 1817691 A	1-7
A	JP 2017-114207 A (KAWASAKI HEAVY IND LTD.) 29 June 2017 & US 2019/0001998 A1 & WO 2017/110748 A1 & CN 108367758 A	1-7
A	WO 2017/174291 A1 (SIEMENS AKTIENGESELLSCHAFT) 12 October 2017 & EP 3408156 A1 & DE 102016205490 A1	1-7

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2017105228 A **[0005]**