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(54) A CONNECTION MODULE FOR A NOISE SHIELDING DEVICE

(57) In a noise shielding device (100), two parallel panels (110) are connected to each other by means of a plurality of connection modules (1). Each module (1) can be made by injection moulding, and has a base element (2) and a suspended mass element (3), connected to the two panels (110). The perimeter shape of the edge (33) of the suspended mass element (3), viewed in a projection along the thickness direction (X-X), is internal to the internal shape of an opening (23) of the base element (2). Leg-shaped connection elements (5) connect the base element (2) and the suspended mass element (3).

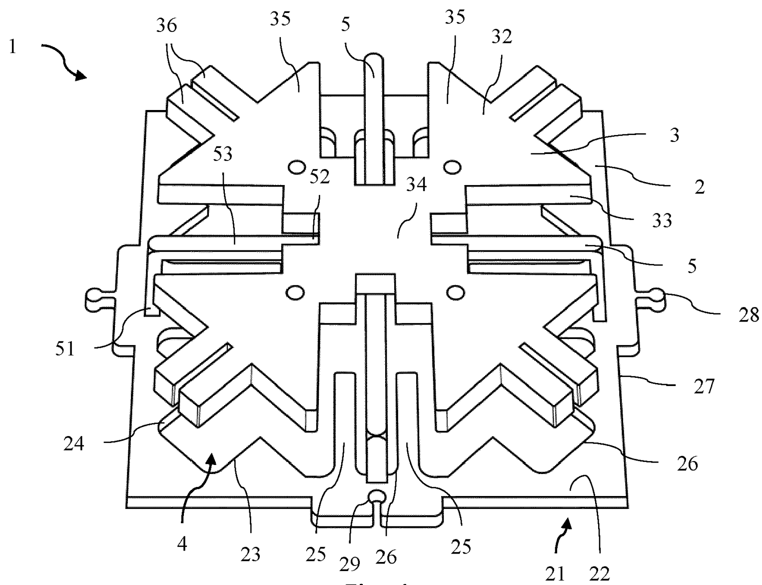

Fig. 1

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Description

Technical field

[0001] The present invention is developed in the field of acoustic noise shielding.

Prior art

[0002] Traditionally, acoustic insulation is made with panels formed by a single layer or multiple layers. When a sound is transmitted from a first environment, upstream of the panel, to a second environment, downstream of the panel, the efficacy of the acoustic insulation of the panel is expressed by means of the sound-insulating power (transmission loss), i.e. a ratio in decibels of the sound pressure that is transferred to the downstream environment to the sound pressure incident on the panel in the upstream environment.

[0003] The sound-insulating power varies based on the frequency of the sound and the physical properties of the panel, in particular its density and its stiffness or elasticity. In the multilayer panels, stiffer layers and more elastic layers are usually alternated. Such a panel can be physically modelled as a system with a series of masses and springs, which reduce the propagation of the sound between the two sides of the panel.

[0004] The choice of materials for the layers of the panel is therefore essential for the performance of the traditional panels. The materials that make up the most effective panels are relatively expensive.

[0005] It is then worth noting that in the most traditional applications, the increase in performance of a panel follows an increase in thickness and weight.

[0006] Acoustic shielding panels based on the metamaterial technology are also known in the art. Unlike traditional panels, where the stiffness and mass properties are determined by the elasticity and density of the microscopic structure of the chosen materials, as well as by their thickness, in metamaterials multiple macroscopic components are connected to each other in such a way as to confer the desired properties of mass and stiffness.

[0007] This has the potential to significantly reduce the costs of the acoustic shielding devices. In fact, in them it is no longer necessary that the material inherently has the desired properties of density and elasticity, but the required properties can be obtained by conferring to the material an appropriate three-dimensional shape. Therefore, significantly cheaper and eco-sustainable materials can be potentially chosen, as long as they are suitably shaped.

[0008] In addition, metamaterials allow to achieve high performance with lower weights and thicknesses than the traditional panels.

[0009] Examples of metamaterial-based noise and vibration shielding devices are described in documents WO 2019072746 and WO 2019141794. In them, the panel is formed by substantially cubic modules connected to each other. Each module has planar mass elements arranged along the faces of the cube, without the faces of the cube being joined together along the edges. Instead, the faces of the cube are connected by stiffening elements placed inside the cube, with various possible substantially linear conformations, in particular straight or curvilinear, like for example circular or arched.

[0010] Similar shielding devices were made initially by 3D printing, and then by other serial, and therefore cheaper, industrial processes. However, there is the need to implement other serial production processes, and optimise the structure of metamaterial shielding devices for this purpose.

Summary of the invention

[0011] Aim of the present invention is to allow the realization of acoustic shielding devices based on metamaterials, which are realizable with simpler and economically competitive industrial processes.

[0012] This and other aims are achieved thanks to the application of a connection module for the realization of a noise shielding device, and by an acoustic shielding device, according to any one of the appended claims.

[0013] Two panels of the device can be connected to each other by means of multiple connection modules. Each connection module comprises a base element and a suspended mass element, spaced apart from each other in a thickness direction and connected to each other by means of connection elements. A first face of the base element is provided for connection to a first panel of the device, and a second face of the suspended mass element is provided for connection to the second panel.

[0014] A perimeter edge of the suspended mass element, and an inner edge of an opening of the base element, are shaped so that, in a projection in the thickness direction, the shape of the suspended mass element is internal to the shape of the opening of the base element.

[0015] Thanks to this shape, the module can be made simply by injection moulding. The cost of injection moulding itself, and of the materials suitable for injection moulding, for example regenerated PVC, are drastically lower than 3D moulding, and more competitive than the traditional panels. The regenerated PVC also makes the product eco-sustainable.

[0016] At the same time, by optimising the shape of the suspended mass element and of the connection elements, the desired mass and stiffness properties can be obtained in order to achieve an optimal sound-insulating power, with limited thicknesses and weights.

[0017] Further features and advantages of the invention will be recognisable by a person skilled in the art from the following detailed description of exemplary embodiments of the invention.

Brief description of the figures

[0018] For a better understanding of the following detailed description, some embodiments of the invention are illustrated in the accompanying drawings, wherein:

- figure 1 shows a perspective view of a connection module for a noise shielding device, according to an embodiment of the invention,
- figure 2 shows some connection modules like the one in figure 1, side by side and interconnected with each other,
- figures 3 and 4 show front connection modules according to alternative embodiments to figure 1,
- figure 5 schematically shows a side view of a portion of a noise shielding device according to an embodiment of the invention,
- figure 6 and figure 7 schematically show front views of two noise shielding devices according to alternative embodiments of the invention.

DETAILED DESCRIPTION

[0019] A noise shielding device is indicated in the figures by the numeral 100. The shielding device 100 comprises two stiff panels 110, arranged parallel to each other, spaced apart from each other in a thickness direction X-X, and facing each other in the thickness direction X-X. The two panels 110 therefore delimit a gap 120 between them, shown in figure 5.

[0020] The two panels 110 may be made in a known manner in one or more layers, without, however, the panels 110 necessarily having significant noise shielding properties per se.

[0021] The shielding device 100 further comprises a plurality of connection modules 1, preferably identical to each other. Therefore, the modules 1 can be realized in series and used in the most appropriate number and position for the specific desired application.

[0022] The modules 1 are arranged between the two panels 110, inside the gap 120, and connect the two panels 110 to each other. It is worth noting that the modules 1 can be provided separately from the panels 110, and subsequently assembled with panels 110 of simple realization and easily available, to make a shielding device 100. In the following, a single connection module 1 will be described with reference to the characteristics of all modules 1.

[0023] The connection module 1 is realizable by injection moulding, and is preferably formed in a single piece. The preferred material for the connection module 1 is polyvinylchloride (PVC), specifically regenerated PVC.

[0024] With reference to figures 1 to 5, the module 1 comprises a base element 2 and a suspended mass element 3, connected to each other. The base element 2 and the suspended mass element 3 each comprise a first face 21, 31 facing toward a first of the two panels 110, and a second face 22, 32, opposite the respective first face 21, 31 and facing toward a second of the two panels 110.

[0025] The first face 21 of the base element 2 is configured for connection to the first panel 110 and is in contact with the first panel 110, while the first face 31 of the suspended mass element 3 is spaced apart from the first panel 110. The second face 22 of the base element 2 is spaced apart from the second panel 110, while the second face 32 of the suspended mass element 3 is configured for connection to the second panel 110 and is in contact with the second panel 110. Therefore, the base element 2 and the suspended mass element 3 are spaced apart or staggered from each other in the thickness direction X-X.

[0026] For the purpose of connection with the panels 110, the first face 21 of the base element 2 and the second face 32 of the suspended mass element 3 are preferably substantially planar.

[0027] It is worth noting that multiple modules 1 of the device 100, arranged between the same panels 110, can all have the base element 2 connected to the same first panel 110 and the suspended mass element 3 connected to the same second panel 110, or each panel can be connected to the base element 2 of at least one module 1 and to the suspended mass element 3 of at least another module 1. It is to be understood that, for each module 1, the first face 21 of the base element 2 and the second face 32 of the suspended mass element 3 are fixed to two distinct panels 110.

[0028] The suspended mass element 3 has a perimeter edge 33, around the second face 32, with a first predetermined shape, also referred to below as the shape of the suspended mass element 3. The preferred shape for the suspended mass element 3 is illustrated in figures 1 and 2. Figures 3 and 4 show other simplified examples, with suspended mass elements of rhomboidal and circular shape.

[0029] For the purpose of the realization by injection moulding, the base element 2 has a through opening 23 having an inner edge 24 with a second predetermined shape, also referred to below as the shape of the opening 23. The first predetermined shape, when projected along the X-X thickness direction, is internal to the second predetermined shape. A projection view along the thickness direction X-X is shown in Fig. 2. In other words, the shape of the suspended mass element 3 is such that the suspended mass element, if translated along the thickness direction X-X would be suitable to be contained in the opening 23 of the base element 2. However, this translation is prevented in the preferred embodiments for the connection modes between the suspended mass element 3 and the base element 2, detailed below.

[0030] With regard to the shapes of the suspended mass element 3 and of the opening 23 of the base 2, it is worth noting that, as is known, injection moulding entails pouring liquid material between two half-moulds, causing the liquid material to solidify, and separating the half-moulds from each other. The described conformation of the suspended mass element 3 and of the opening 23 of the base element 2 allows the separation of the half-moulds also following the solidification of the material.

[0031] In the preferred embodiment, to optimise noise damping, the shape of the suspended mass element 3 defines in the second face 32 a central portion 34 of the suspended mass element 3 and a plurality of lobes 35 of the suspended mass element 3. The lobes 35 are distributed circumferentially around the central portion 34, and protrude radially from the central portion 34. Preferably, each lobe 35 has one or more tabs 36 extending predominantly in the radial direction.

[0032] The conformation of the lobes 35 and of the tabs 36 can be chosen by the persons skilled in the art in such a way as to:

- balance between them the masses of the base element 2 and of the suspended mass element 3, as well as the surfaces of the first face 21 of the base element 2 and of the second face 32 of the suspended mass element 3, optimising the connection with the two panels 110, and
- optimise the mass distribution, both of the base element 2 and of the suspended mass element 3, in planes perpendicular to the thickness direction X-X, avoiding in particular that each of them presents solid areas of convex shape with excessive dimensions, which would confer excessive stiffness to the component in question.

[0033] In this description, by radial direction is meant a direction, in a plane perpendicular to the thickness direction X-X, extending away from a centre, placed in the central portion 34 of the suspended mass element 3. Instead, by circumferential direction is meant a direction, in a plane perpendicular to the thickness direction X-X, which wraps around the aforementioned centre. The radial, circumferential and thickness directions therefore identify a system of cylindrical coordinates.

[0034] The perimeter edge 33 of the suspended mass element 3 and the inner edge 24 of the opening 23 of the base element 2 delimit a gap 4 between them. In particular, the perimeter edge 33 and the inner edge 24 are spaced apart from each other in the thickness direction X-X and/or in the radial direction.

[0035] In preferred embodiments, the inner edge 24 of the base element 2 develops at least in part along the perimeter edge 33 of the suspended mass element 3, although spaced apart therefrom. Therefore, some portions of the inner edge 24 and of the perimeter edge 33 (even if they were curvilinear) can be substantially parallel, i.e. be positioned at a substantially constant distance from each other, along their length extension.

[0036] In the illustrated embodiment, the shape of the opening 23 has a plurality of peninsula portions 25 which, in a projection in the thickness direction X-X, are positioned between consecutive lobes 35 of the suspended mass element 3. The peninsula portions 25, in a projection in the thickness direction X-X, extend radially towards the central portion 34 of the suspended mass element 3.

[0037] In addition, the shape of the opening 23 has a plurality of gulf portions 26 joining consecutive peninsula portions 25.

[0038] The connection module 1 has a plurality of connection elements 5 connecting the base element 2 and the suspended mass element 3. The connection elements 5 are preferably shaped as connection legs, i.e. elements with predominantly linear development, without necessarily being straight, for example straight, curvilinear, broken lines, or a combination thereof.

[0039] The connection elements 5 are also made in one piece with the base element 2 and the suspended mass element 3, in the same injection moulding process. Therefore, all these elements are made of the same material, substantially stiff.

[0040] The leg conformation of the connection elements 5 confers stiffness but also elasticity to the module 1. In fact, depending on the frequency of a vibration, for example acoustic, which is transmitted in sequence from the first panel 110, to the base portion 2, to the connection elements 5, to the suspended ground portion 3, to the second panel 110, or vice versa, the stiffness or elasticity properties of the connection elements 5 are prevalent.

[0041] Therefore, at the frequencies that are intended to be damped the most, the connection elements 5 can be designed so that the connection module 1 is similar to a mass and spring system, with the masses represented by the base and suspended mass elements 2, 3, and the springs represented by the connection elements 5.

[0042] Each connection element 5 has a first end portion 51 connected to the base element 2, a second end portion 52 connected to the suspended mass element 3, and a joining portion 53 connecting the first and second end portion 51, 52. The connection element 5 can advantageously develop substantially linearly between the first and second end portion 51, 52. Preferably, the two end portions 51, 52 are spaced apart from each other at least in a radial direction. The spacing in the radial direction allows to increase the length of the connection elements 5, increasing the elasticity properties thereof.

[0043] For this purpose, preferably the connection elements 5 connect the base element 2 to the central portion 34 of the suspended mass element 3. More in detail, the connection elements 5 connect gulf portions 26 of the opening 23 of the base element 2 with the central portion 34 of the suspended mass element 3.

[0044] While the central portion 34 is connected to the connection elements 5, the lobes 35 increase the mass of the suspended mass element 3 and the surface of its second face 32 useful for connection to the second panel 110.

[0045] For the purpose of the realization by injection moulding, the joining portions 53 of the connection elements 5, in a projection along the thickness direction X-X, join the shape of the suspended mass element 3 to the shape of the opening 23, and are preferably external to the shape of the suspended mass element 3 and internal to the shape of the opening 23. Therefore, in a projection in the thickness direction X-X, the shape of the opening 23 encloses the assembly of the shape of the suspended mass element 3 and of the joining portions 53 of the connection elements 5.

[0046] It is worth pointing out that some of the gulf portions 26, in a projection in the thickness direction X-X, are arranged around lobes 35 of the suspended mass element 3, while other gulf portions 26, always in a projection, can be arranged around connection elements 5. At these latter gulf portions 26, the inner edge 24 of the opening 23 may also deviate significantly from the outer edge 33 of the suspended mass element 3.

[0047] The base element 2, in addition to the opening 23 with the inner edge 24, has an outer contour 27. In the illustrated embodiments, the outer contour 27 has four sides, and is substantially shaped as a square. However, other shapes are possible, preferably such as to allow multiple modules 1 to be placed side by side along the sides of their outer contours 27, such as for example triangular or hexagonal shapes, or even other shapes, such as circular shapes.

[0048] In the preferred embodiment, the outer contour 27 of the base element 2 has a plurality of interlocking portions 28, 29, shaped for fixing multiple connection modules 2, preferably identical, side by side to one another. For example, the interlocking portions 28, 29 may comprise male interlocking portions 28, with an interlocking element protruding from the outer contour 27, and female interlocking portions 29, recessed towards the inside of the outer contour 27 and shaped to receive respective male interlocking portions 28.

[0049] Each side of the outer contour 27 may have a single interlocking portion 28, 29 or multiple interlocking portions 28, 29, which may all be male interlocking portions 28, all female interlocking portions 29, or a combination thereof.

[0050] It is worth noting that, in the shielding device 100, the connection modules 1 can be arranged spaced apart or in contact with each other, preferably interlocked with each other through the interlocking portions 28, 29. This is shown schematically in figures 6 and 7, where for simplicity's sake the modules 1 have been represented substantially square, with a low level of detail, and dashed as they are covered by one of the panels 110.

[0051] So far, a shielding device 100 has been described, two panels 110 of which have been mentioned, with a single gap 120 between them, and connection modules 1 in this gap 120. Embodiments with three or more panels 110, which delimit two or more gaps 120, and multiple connection modules 1 in each gap 120 for connecting pairs of consecutive panels 110 are also possible.

[0052] Obviously, a person skilled in the art will be able to make numerous equivalent modifications to the variants set forth above, without thereby departing from the scope of protection as defined by the appended claims.

Claims

1. Connection module (1) for a noise shielding device (100), the connection module (1) being obtainable by injection moulding and comprising:

   - a base element (2) having a first face (21) configured for connection to a first panel (110) of the shielding device (100),
   - a suspended mass element (3) spaced apart from the base element (2) in a thickness direction (X-X), the suspended mass element (3) having a second face (32) configured for connection to a second panel (110) of the shielding device (100),
   - a plurality of connection elements (5) connecting the base element (2) and the suspended mass element (3),

   wherein:

   - the suspended mass element (3) has a perimeter edge (33) with a first predetermined shape,
   - the base element (2) has an opening (23) having an inner edge (24) with a second predetermined shape,
   - the first predetermined shape, when projected along the thickness direction (X-X), is internal to the second predetermined shape.

2. Connection module (1) according to claim 1, wherein the perimeter edge (33) of the suspended mass element (3) and the inner edge (24) of the base element (2) delimit a gap (4) therebetween.

3. Connection module (1) according to claim 1 or 2, wherein the inner edge (24) of the base element (2) extends at least in part along the perimeter edge (33) of the suspended mass element (3), spaced apart from the perimeter edge (33) of the suspended mass element (3).

4. Connection module (1) according to any one of claims 1 to 3, wherein:

   - each connection element (5) has a first end portion (51) connected to the base element (2), a second end portion (52) connected to the suspended mass element (3), and a joining portion (53) connecting the first and second end portions (51, 52), and
   - the joining portions (53) of the connection elements (5), when projected along the thickness direction (X-X), are external to the first predetermined shape and internal to the second predetermined shape.

5. Connection module (1) according to claim 4, wherein

each connection element (5) extends substantially linearly between the first end portion (51) and the second end portion (52).

6. Connection module (1) according to any one of claims 1 to 5, wherein the suspended mass element (3) has a central portion (34) and a plurality of lobes (35) which are positioned around the central portion (34).

7. Connection module (1) according to claim 6, wherein the connection elements (5) connect the base element (2) to the central portion (34) of the suspended mass element (3).

8. Connection module (1) according to any one of claims 1 to 7, wherein the base element (2), the suspended mass element (3) and the connection elements (5) are formed in one piece.

9. Connection module (1) according to any one of claims 1 to 8, wherein the base element (2) has an outer contour (27), which has a plurality of interlocking portions (28, 29) shaped for fixing multiple identical connection modules (1) side by side.

10. Shielding device for noise reduction (100), comprising:

- two panels (110) parallel and spaced apart from each other in a thickness direction (X-X),
- a plurality of connection modules (1) according to any one of claims 1 to 9, arranged between the two panels (110),

wherein, for each connection module (1), the first face (21) of the base element (2) and the second face (32) of the suspended mass element (3) are fixed to two distinct of said panels (110).

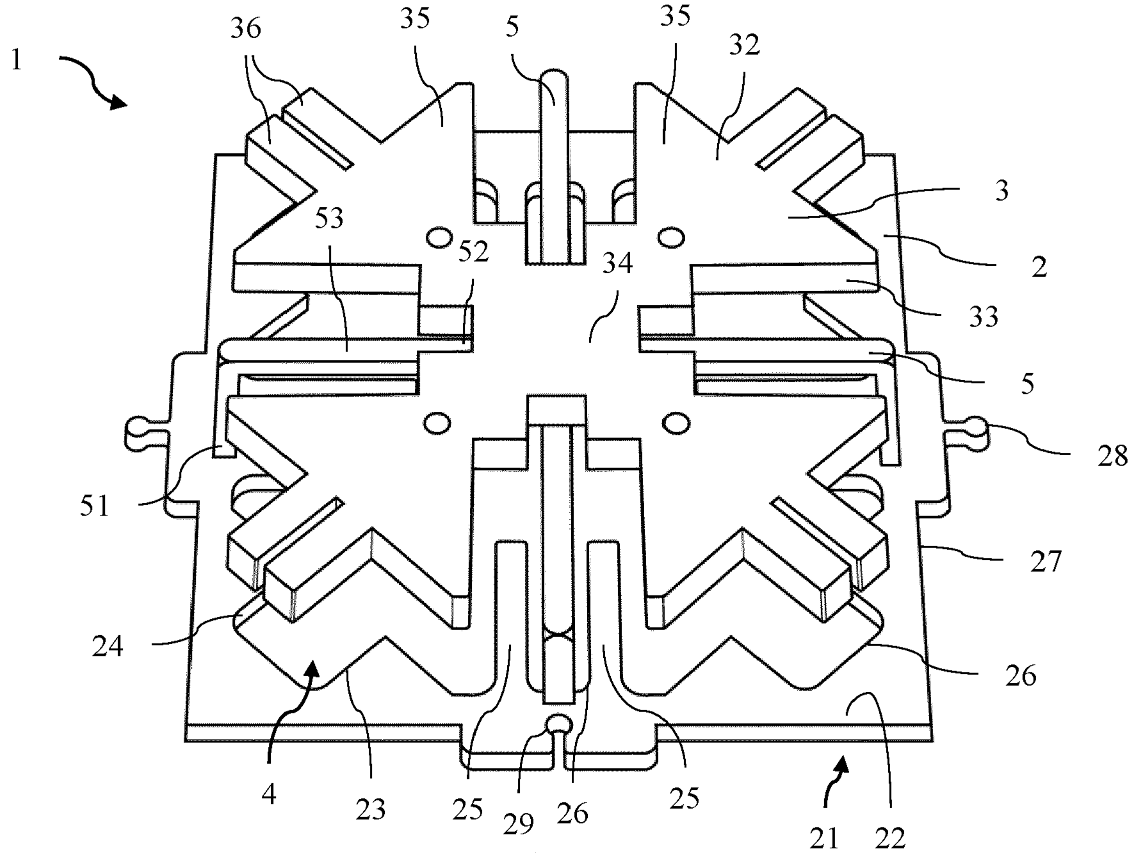
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Fig. 1

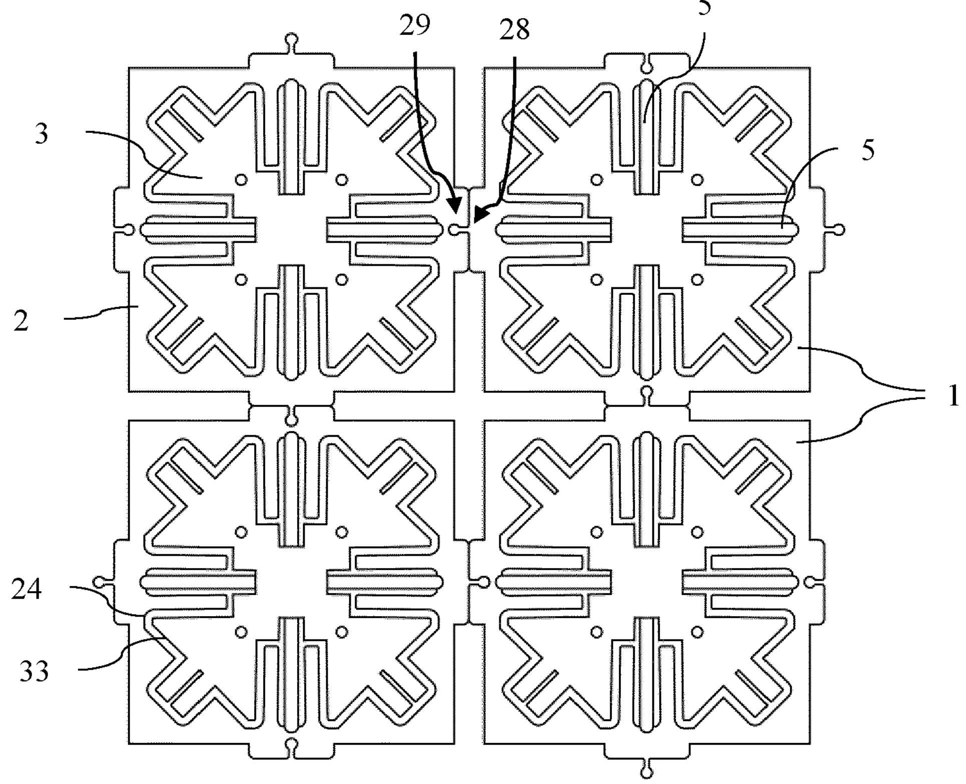
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Fig. 2

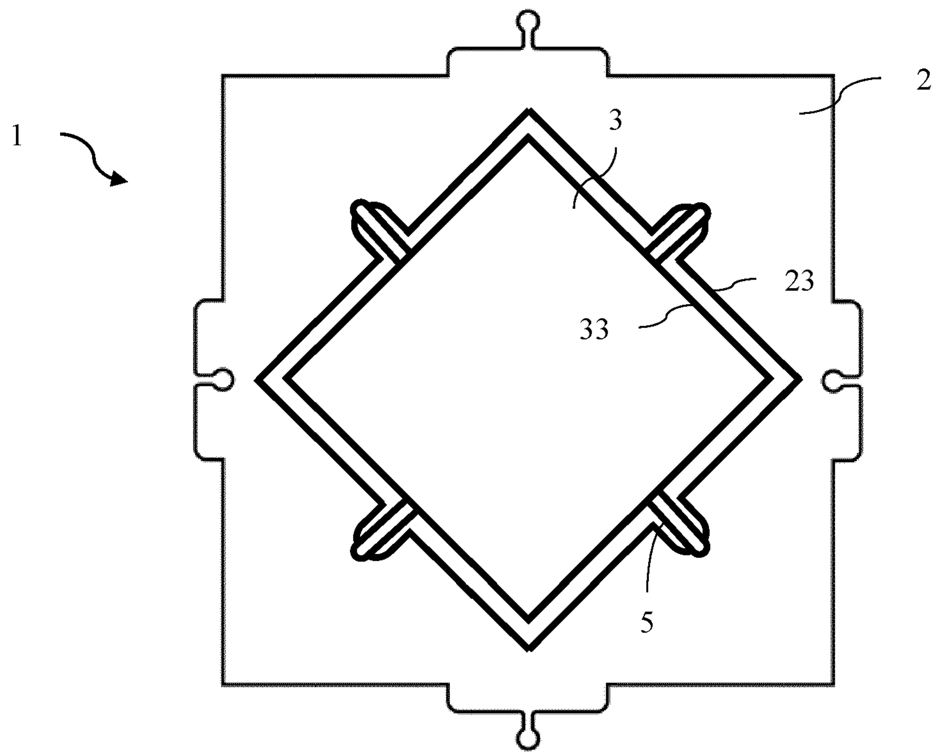

Fig. 3

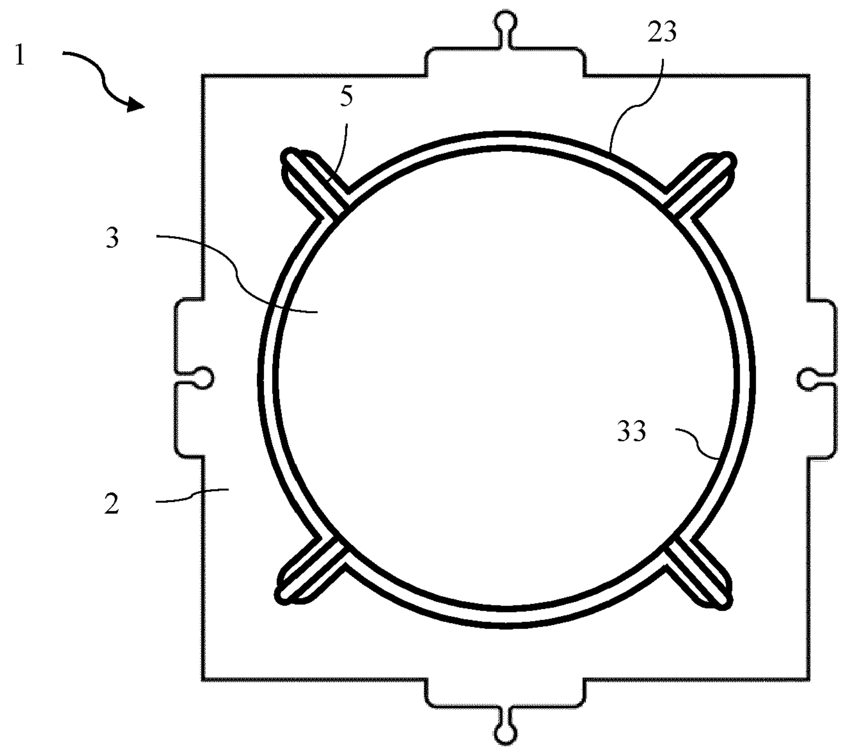

Fig. 4

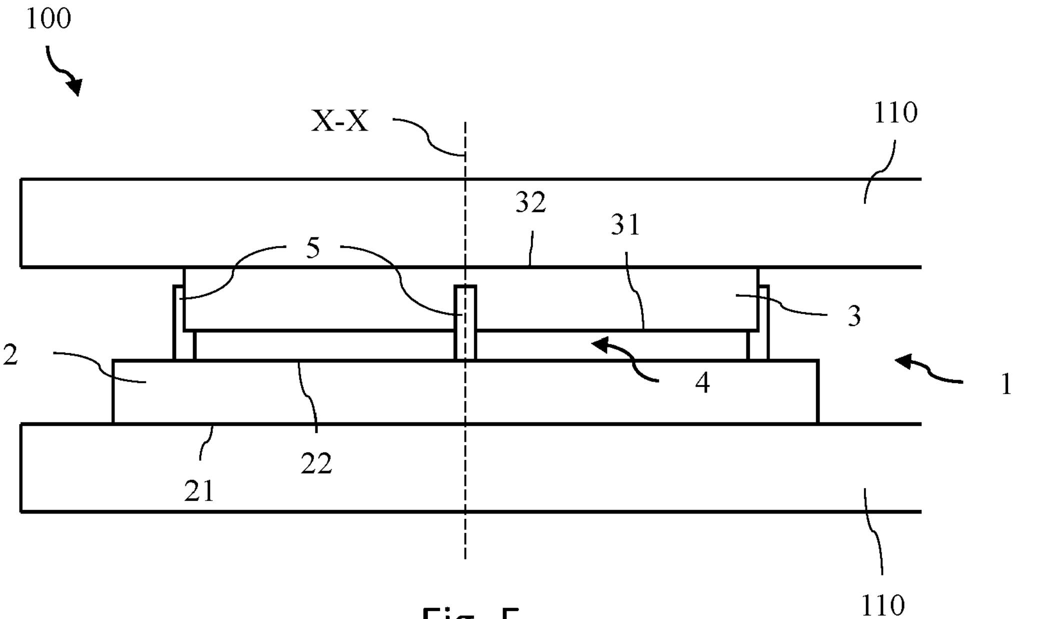

Fig. 5

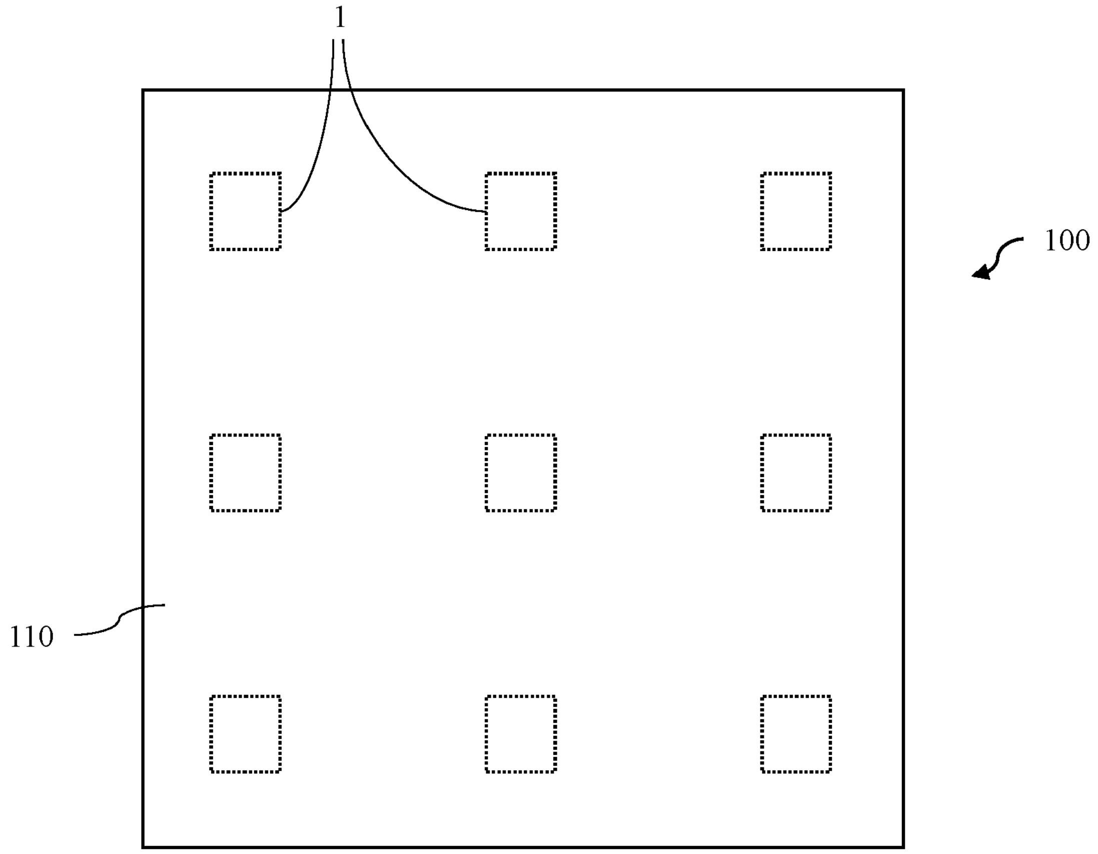

Fig. 6

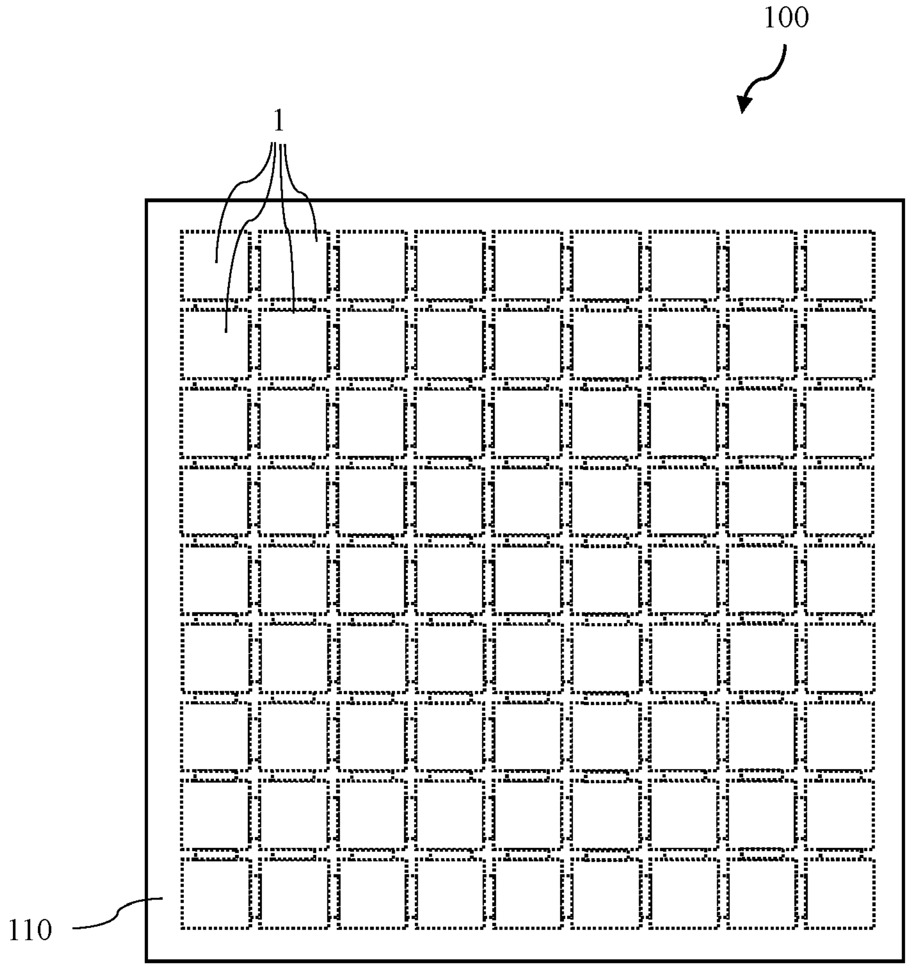

Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 23 19 9711

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	KR 200 471 099 Y1 (SEONG Y) 3 February 2014 (2014-02-03) * paragraphs [0001], [0026]; figure 2 * -----	1-10	INV. G10K11/162
A	WO 2022/013274 A1 (PHONONIC VIBES S R L [IT]) 20 January 2022 (2022-01-20) * abstract * * page 14, line 25 - page 15, line 4; figures 7A, 7B * -----	1-10	
A	CN 114 619 726 A (JIANGSU SCIENCE AND TECHNOLOGY UNIV ET AL.) 14 June 2022 (2022-06-14) * paragraphs [0022], [0023]; figures 1,2 * -----	1-10	

TECHNICAL FIELDS SEARCHED (IPC)

G10K
E04B
E04C
E04F
F16B
B28B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	30 January 2024	Mirkovic, Olinka

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