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(54) **REACTOR**

(57) A reactor that can suppress magnetic flux from hitting the end surfaces of the magnetic sensor and that can reduce eddy current loss and the amount of generated heat can be obtained. The reactor (10) includes an air-core coil (1) formed by winding a conductive member in a cylindrical shape, a magnetic body (2) arranged to face an inner circumferential surface that is a hollow por-

tion of the air-core coil (1) orthogonal to a winding axial direction; and a magnetic sensor (3) formed by winding the conductive member to detect a magnetic state of the reactor (10). The magnetic sensor (3) is wound around an outer circumference of the magnetic body (2) other than an extended region of the inner circumferential surface of the air-core coil (1).

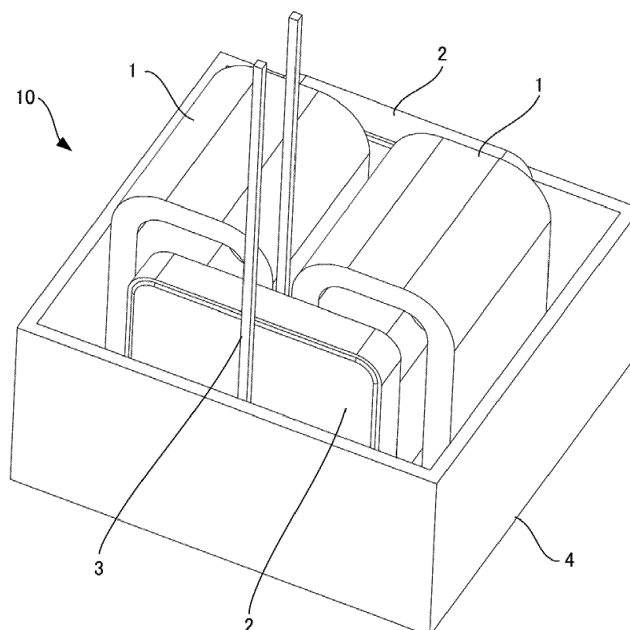


Fig. 1

DescriptionCROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is based upon and claims the benefit of priority from Japan Patent Application No. 2021-040330, filed on March 12, 2021, the entire contents of which are incorporated herein by reference.

FIELD OF INVENTION

[0002] The present disclosure relates to a reactor including a magnetic sensor formed by conductive members.

BACKGROUND

[0003] Reactors are used in various applications such as office automation apparatuses, solar power generation systems, automobiles, etc. The reactor includes a coil and a magnetic body arranged on both end surfaces which are orthogonal to the winding axial direction of the coil. The coil is electrically connected to external devices, and generates magnetic flux when electric power is supplied from the external devices. The magnetic body becomes a magnetic path through which the magnetic flux generated by the coil passes. Accordingly, the reactor is an electromagnetic component that converts electric energy into magnetic energy, and stores and releases said energy.

[0004] The reactor may include a magnetic sensor formed by winding conductive members to detect magnetic field. To detect more magnetic flux, the magnetic sensor is arranged to face the end surface orthogonal to the winding axial direction of the coil and between the coil and the magnetic body. That is, the magnetic sensor is arranged in the extended region of the inner circumferential surface that is the hollow portion of the coil.

SUMMARY OF INVENTIONPROBLEMS TO BE SOLVED BY INVENTION

[0005] An air-core coil may be used as the coil. When the magnetic body is inserted in the inner circumference of the coil, since the magnetic body becomes the magnetic path, the magnetic flux is unlikely to hit the end surface of the conductive member forming the magnetic sensor, except for the leakage flux. On the other hand, when the air-core coil is used, the magnetic flux generated from the air-core coil expands in the boundary between the air-core coil and the magnetic body, and the amount of the magnetic flux hitting the end surface of the conductive member forming the magnetic sensor is large in comparison with a case in which the magnetic body is inserted in the inner circumference of the coil.

[0006] In detail, as illustrated in Fig. 11, the magnetic flux generated by the air-core coil 101 flows toward the magnetic body 102 (an arrow in Fig. 11 indicates the flow of the magnetic flux). Accordingly, the magnetic flux expands from the end portion of the air-core coil toward the magnetic body 102 (a portion circled by a dashed line in Fig. 11), the leakage flux does not pass through the inner circumference of the magnetic sensor 103 and may hit the end surface of the magnetic sensor 103. Similarly, the magnetic flux flowing through the magnetic body 102 may flow toward the air-core coil 101 and may hit the end surface of the magnetic sensor 103.

[0007] When the magnetic flux hits the end surface of the magnetic sensor, eddy current loss is produced in the magnetic sensor. Therefore, as the amount of the magnetic flux hitting the end surface of the magnetic sensor increases, eddy current loss also increases. Accordingly, the magnetic sensor generates heat in proportion to the increase in eddy current loss, and as a result, the amount of heat generated by the reactor also increases.

[0008] The present disclosure has been made to address the above described problem, and the objective is to provide a reactor that can suppress magnetic flux from hitting the end surfaces of the magnetic sensor and that can reduce eddy current loss and the amount of generated heat.

MEANS TO SOLVE THE PROBLEM

[0009] A reactor of the present disclosure includes:

an air-core coil formed by winding a conductive member in a cylindrical shape;

a magnetic body arranged to face an inner circumferential surface that is a hollow portion of the air-core coil orthogonal to a winding axial direction; and

a magnetic sensor formed by winding the conductive member to detect a magnetic state of the reactor,

wherein the magnetic sensor is wound around an outer circumference of the magnetic body other than an extended region of the inner circumferential surface of the air-core coil.

EFFECT OF INVENTION

[0010] According to the present disclosure, a reactor that can suppress magnetic flux from hitting the end surfaces of the magnetic sensor and that can reduce eddy current loss and the amount of generated heat can be obtained.

BRIEF DESCRIPTION OF DRAWINGS

[0011]

Fig. 1 is a perspective view illustrating an entire configuration of a reactor according to a first embodiment.

Fig. 2 is a figure illustrating an inner circumference surface of an air-core coil.

Fig. 3 is a figure illustrating a flow of magnetic flux in the first embodiment.

Fig. 4 is a perspective view illustrating an entire configuration of a reactor according to a second embodiment.

Fig. 5 is a plan view of the reactor according to the second embodiment.

Fig. 6 is a schematic diagram illustrating lengths of a protruding portion and the air-core coil.

Fig. 7 is a figure illustrating a flow of the magnetic flux in a case the protruding portion is not provided.

Fig. 8 is a figure illustrating a flow of magnetic flux in the second embodiment.

Fig. 9 is a perspective view illustrating an entire configuration of a comparative example 1.

Fig. 10 is a plan view illustrating an entire configuration of a comparative example 2.

Fig. 11 is a figure illustrating a flow of the magnetic flux in a case the protruding portion is provided at a conventional position.

EMBODIMENTS

(First Embodiment)

[0012] A reactor according to a first embodiment is described with the reference to figures. Fig. 1 is a perspective view illustrating an entire configuration of the reactor. The reactor 10 is an electromagnetic component that converts electric energy into magnetic energy, stores and releases said energy, and is used in various applications such as office automation apparatuses, solar power generation systems, automobiles, etc. The reactor of the first embodiment includes an air-core coil 1, a magnetic body 2, a magnetic sensor 3, and a casing 4.

[0013] The air-core coil 1 is formed by one flat rectangular conductive member coated with an insulation coating such as enamel. The air-core coil 1 is formed by winding the conductive member in a cylindrical shape while displacing the winding position in the winding axial direction, and an inner circumference portion thereof is a hollow portion to which the magnetic body 2 is not inserted. In the present embodiment, the air-core coil 1 is a flat wire edgewise coil formed by copper wires. However, types of wire materials and winding methods of the air-core coil 1 is not limited, and other forms may be applied.

[0014] The air-core coil 1 in which the magnetic body is not inserted into the inner circumference is characterized in that the inductance value is constant regardless of the current value flowing through the coil. In contrast, the coil in which the magnetic body is inserted in the inner circumference is characterized in that the magnetic body saturates and the inductance value decreases as the current value flowing through the coil increases. Therefore, the characteristics largely differ between the air-core coil 1 of the present invention and the coil in which the magnetic body is inserted in the inner circumference.

[0015] Two air-core coils are provided. The air-core coil 1 is arranged side by side via a gap so that the winding axial directions become parallel to each other. Note that in the air-core coil 1, an end portion of the conductive member is electrically connected to external devices, and magnetic flux is generated when electricity is supplied from the external devices.

[0016] The magnetic body 2 becomes a magnetic path through which the magnetic flux generated by the air-core coil 1 flows. The magnetic body 2 may be a powder magnetic core, a ferrite core, a laminated steel sheet, or a metal composite. The metal composite is a magnetic body formed by kneading a magnetic powder and a resin and curing the resin.

[0017] The magnetic body 2 has a substantially rectangular shape, and two magnetic bodies 2 is provided. The magnetic bodies 2 each arranged to face an inner circumferential surface of the air-core coil 1 orthogonal to the winding axial direction. The inner circumferential surface of the air-core coil 1 is a surface orthogonal to the winding axial direction of the hollow portion of the cylindrical air-core coil 1 (hatching portion in Fig. 2). That is, the magnetic bodies 2 are arranged to face each other so as to sandwich the air-core coil 1 therebetween.

[0018] The magnetic sensor 3 detects the magnetic state of the reactor 10. In detail, the magnetic sensor 3 detects the magnetic flux flowing in the reactor 10. The magnetic sensor 3 is formed by the conductive member. The magnetic sensor 3 is formed by winding the conductive member, and for example, a number of windings is one or less. By reducing number of windings to one or less, a process of winding the conductive member is minimized, improving productivity thereof and reducing the material cost. The magnetic sensor 3 has a substantially U-shape in which two portions of the conductive member are bent in substantially right angle to form a width portion and two length portion extending from both sides of the width portion.

[0019] The magnetic sensor 3 is arranged at regions other than an extended region of the inner circumferential surface of the air-core coil 1. The magnetic sensor 3 is wound around an outer circumference of a substantially central portion of one of the magnetic bodies 2. In detail, the width portion of the magnetic sensor 3 is sandwiched by the magnetic body 2 and the casing 4, and the two length portions of the magnetic sensor 3 sandwich the magnetic body 2. The magnetic sensor 3 is arranged between two air-core coils 1. Note that since the magnetic sensor 3 of the present embodiment does not measure total amount of the magnetic flux, but only detects changes in the magnetic flux for each time, the detection function would not be affected even when the magnetic sensor 3 is arranged between two air-core coils 1.

[0020] The magnetic sensor 3 is integrally molded and fixed with the magnetic body 2 by resins (unillustrated). For example, as types of the resins, epoxy resins, unsaturated polyester resins, urethane resins, BMC (Bulk Molding Compound), PPS (Polyphenylene Sulfide), and PBT (Polybutylene Terephthalate), etc., may be cited.

[0021] The cross-sectional area of the conductive member forming the magnetic sensor 3 is smaller than the cross-sectional area of the conductive member forming the air-core coil 1. Although the cross-sectional area is not limited, for example, the cross-sectional area of the conductive member forming the magnetic sensor 3 is approximately one sixth of the conductive member forming the air-core coil 1. That is, when the cross-sectional area of the conductive member forming the air-core coil 1 is 6 mm², the cross-sectional area of the conductive member forming the magnetic sensor 3 is 1 mm².

[0022] Furthermore, the reactor 10 includes a temperature sensor (unillustrated) to detect the temperature of the reactor 10. The temperature sensor is arranged between the air-core coil 1. Note that the temperature sensor may be integrally molded and fixed together with the magnetic body 2 and the magnetic sensor 3, or may be inserted and fixed to a holding portion in the resin.

[0023] The casing 4 has a box-shape with an upper surface opened. The casing 4 houses the air-core coil 1, the magnetic body 2, the magnetic sensor 3, and the temperature sensor. For example, the casing 4 is formed of a light weight metal with high thermal conductivity, such as an aluminum alloy and has heat dissipation effect. Note that, after the air-core coil 1, the magnetic body 2, the magnetic sensor 3, and the temperature sensor are housed in the casing 4, a filler may be injected into the casing 4. As the filler, relatively soft resins with high thermal conductivity such as silicone resins, urethane resins, epoxy resins, and acrylic resins is suitable.

(Action)

[0024] As illustrated in Fig. 11, conventionally, a magnetic sensor 103 is arranged in an extended region of an inner circumferential surface of the air-core coil 101 to detect more magnetic flux. Since the magnetic flux generated from the air-core coil 101 expands toward a magnetic body 102 and since the magnetic flux flowing in the magnetic body 102 flows toward the air-core coil 101, a part of the magnetic flux may hit not only the inner circumferential portion of the magnetic sensor 103, but also the end surface of the conductive metal. When the magnetic flux hits the end surface of the conductive member, eddy current loss increases, and as a result, the heat generation becomes larger.

[0025] However, in the present embodiment, the magnetic sensor 3 is arranged is not arranged in the extended region of the inner circumferential surface of the air-core coil 1, and is arranged at the substantially central portion of the magnetic

body 2 and between the air-core coil 1. Therefore, as illustrated in Fig. 3, the magnetic flux generated from the air-core coil 1 enters the magnetic body 2, passes through the inner circumference of the magnetic sensor 3 to flow through inside the magnetic body 2, and flows from the magnetic body 2 to the air-core coil 1. That is, the magnetic flux is prevented from hitting the magnetic sensor 3. Furthermore, since the width portion of the magnetic sensor 3 is sandwiched by the magnetic body 2 and the casing 4, and the two length portions of the magnetic sensor 3 is provided in the outer circumference of the magnetic body 2 so as to sandwich the magnetic body 2, the magnetic sensor 3 can detect the magnetic flux flowing in the magnetic body 2 that is the magnetic path.

(Effect)

[0026] As described above, the reactor 10 of the present embodiment includes the air-core coil 1 formed by winding the conductive member, the magnetic body 2 arranged to face the inner circumferential surface the air-core coil 1 orthogonal to the winding axial direction; and the magnetic sensor formed by winding the conductive member around the outer circumference of the magnetic body 2 to detect the magnetic state of the reactor 10. In addition, the magnetic sensor 3 is wound around the outer circumference of the magnetic body 2 other than an extended region of the inner circumferential surface of the air-core coil 1.

[0027] By this, since the magnetic flux is prevented from hitting the magnetic sensor 3, eddy current loss can be suppressed. Accordingly, by suppressing eddy current loss, the heat generation of the magnetic sensor 3 can be suppressed. As a result, eddy current loss of the reactor 10 and the amount of heat generated from the reactor 10 can be reduced. In addition, since the magnetic sensor 3 is arranged in the outer circumference of the magnetic body 2, the change amount of the magnetic flux flowing in the magnetic body 2 that is the magnetic path can be measured, serving as a sensor.

[0028] The cross-sectional area of the conductive member forming the magnetic sensor 3 is smaller than the cross-sectional area of the conductive member forming the air-core coil

1. By this, the magnetic sensor 3 can be downsized, and as a result, the reactor 10 can be downsized.

[0029] Conventionally, when the magnetic sensor 103 is arranged the extended region of the inner circumferential surface of the air-core coil 101, the amount of heat generated by the magnetic sensor 103 becomes large. To improve the heat dissipation, it is required to make the conductive member forming the magnetic sensor 103 thicker, that is, it is required to increase the cross-sectional area and diameter of the conductive member.

[0030] However, in the present embodiment, since the amount of heat generated by the magnetic sensor 3 can be reduces such that it is not required to improve the heat dissipation of the magnetic sensor 3, the cross-sectional area of the conductive member forming the magnetic sensor 3 can be made smaller, and as a result, the diameter of the magnetic sensor 3 can be made smaller. Therefore, the magnetic sensor 3 can be downsized, and as a result, the reactor 10 can be downsized.

[0031] Furthermore, two air-core coils are provided, and the two air-core coils 1 are arranged side by side so that the winding axial directions become parallel to each other. The magnetic sensor 3 is arranged between the air-core coils 1, and the temperature sensor to detect the temperature of the reactor 10 is arranged between the air-core coils 1.

[0032] As described above, since the amount heat generated by the magnetic sensor 3 can be suppressed, the diameter of the magnetic sensor 3 can be made smaller. Therefore, the gap between the air-core coils 1 arranged side by side can be made smaller. The temperature sensor can detect the temperature more precisely when it is arranged at the position closer to the air-core coil 1. Therefore, by arranging the temperature sensor between the air-core coils 1 having smaller gaps therebetween, the temperature of the reactor 10 can be detected more precisely.

[0033] The magnetic sensor 3 is integrally molded and fixed with the magnetic body 2 by resins. By this, since the magnetic sensor 3 is suppressed from being displaced even when the reactor 10 vibrates, excellent detection state can be maintained. Furthermore, by molding the magnetic sensor 3 integrally with the magnetic body 2, a process of fixing the magnetic sensor 3 can be omitted, improving the productivity.

(Second Embodiment)

[0034] A reactor according to a second embodiment will be described with the reference to figures. Note that same configurations and same functions as the first embodiment are labeled with same reference signs and descriptions thereof are omitted, and only different parts are described. Fig. 4 is a perspective view illustrating an entire configuration of the reactor according to the second embodiment. Fig. 5 is a plan view of the reactor according to the second embodiment.

[0035] The reactor 10 according to second embodiment has different numbers of the air-core coils 1, different shapes of the magnetic body 2, and different numbers of the magnetic sensors 3 compared to the first embodiment. Three air-

core coils 1 are arranged side by side via the gaps so that the winding axial directions become parallel to each other. In detail, an air-core coil 1b is arranged at the center, and air-core coils 1a and 1c are arranged at both sides of the air-core coil 1b and sandwich the air-core coil 1b.

[0036] The magnetic body 2 includes a protruding portion 21. This protruding portion 2 is also formed of a powder magnetic core, a ferrite core, a laminated steel sheet, or a metal composite, and becomes a magnetic path through which the magnetic flux flows. The protruding portion 21 extends from a surface facing the air-core coils 1a, 1b, and 1c toward the air-core coils 1a, 1b, and 1c. The magnetic body includes the same number of protruding portions as the number of the air-core coils 1. The protruding portions 21 of respective magnetic bodies 2 sandwich the air-core coils 1 and are arranged to face each other.

[0037] The protruding portions 21 may be inserted into the inner circumferences of the air-core coils 1a, 1b, and 1c. Note that total length of the facing protruding portions 21 inserted in the inner circumference of the air-core coil 1 is equal to or less than half the length of the air-core coil 1 in the winding axial direction. That is, as illustrated in Fig. 6, when the lengths of the facing protruding portions 21 inserted in the inner circumference of the air-core coil 1 in the winding axial direction are respectively L1 and L2, and the length of the air-core coil 1 in the winding axial direction is L3, $(L1 + L2) \leq (L3/2)$ is met. That is, the air-core coil 1 of the present disclosure includes an air-core coil in which equal to or more than half of the inner circumference is hollow.

[0038] Note that a space between the facing protruding portions 21 is not the gap. The gap makes a magnetic gap with predetermined width between the magnetic bodies so that the reduction in the inductance of the reactor 10 is prevented. As described above, since the inductance value of the air-core coil 1 does not depend on the current value and is constant, there is no need to prevent the reduction in the inductance in the first place. Therefore, equal to or more than half of the inner circumference of the air-core coil 1 that is the hollow portion is different from the gap to prevent the reduction in inductance. As described later, the protruding portion 21 is provided to suppress the magnetic flux from expanding and hitting the end surface of the conductive member forming the air-core coil 1.

[0039] Furthermore, the reactor 10 of the present embodiment includes a plate-shape magnetic body 22. Four plate-shape magnetic bodies 22 are provided respectively provided between the air-core coils 1a and 1b, between the air-core coils 1b and 1c, and at both end portions of the magnetic body 2. The plate-shape magnetic body 22 is joined to the magnetic body 2 by, for example, adhesives.

[0040] Three magnetic sensors 3 are provided. The magnetic sensor 3a is provided between the air-core coil 1a and the plate-shape magnetic body 22, the magnetic sensor 3b is provided between the air-core coils 1a and 1b, and the magnetic sensor 3c is provided between the air-core coil 1c and the plate-shape magnetic body 22, in the outer circumference of one of the magnetic bodies 2, respectively. Three magnetic sensors 3a, 3b, and 3c are all provided in the outer circumference of the magnetic body 2 other than the extended region of the inner circumferential surface of the air-core coil 1 orthogonal to the winding axial direction.

(Action)

[0041] Next, the action of the second embodiment is described with the reference to the figures. Fig. 7 is a figure illustrating a flow of the magnetic flux in a case the protruding portion is not provided. Fig. 8 is a figure illustrating a flow of magnetic flux in the second embodiment. Note that arrows in Figs. 7 and 8 indicates a flow of the magnetic flux.

[0042] As described above, since the magnetic flux generated from the air-core coil 1 expands toward the magnetic body 2 and since the magnetic flux flowing in the magnetic body 2 flows toward the air-core coil 1, the magnetic flux hit the end surface of the conductive member forming the air-core coil 1, eddy current loss may increase (surrounded by a dashed circle in Fig. 7).

[0043] However, as illustrated in Fig. 8, by providing the protruding portion 21 to the magnetic body 2, since the magnetic flux generated from the air-core coil 1 flows toward the protruding portion 21, the magnetic flux is suppressed from expanding in the boundary between the air-core coil 1 and the magnetic body 2. Furthermore, the magnetic flux that has flowed the magnetic body 2 also flows in the protruding portion 21 and flows from a tip of the protruding portion 21 to the air-core coil 1. As a result, the magnetic flux is suppressed from hitting the end surface of the conductive member forming the air-core coil 1.

(Effect)

[0044] As described above, in the reactor 10 of the present embodiment, the magnetic body 2 includes the protruding portion 21 extending from the surface facing the air-core coil 1 toward the air-core coil 1. By this, the magnetic flux is suppressed from hitting the end surface of the conductive member forming the air-core coil 1. As a result, eddy current loss of the reactor 10 is reduced, and the amount of heat generation of the reactor 10 is reduced.

(Examples)

[0045] The present disclosure is further described in detail based on examples. Note that the present disclosure is not limited to the following examples.

[0046] Firstly, reactors of examples 1 and 2 and comparative examples 1 and 2 are produced. The examples 1 has the same configuration as the first embodiment (Fig. 1). Meanwhile, as illustrated in Fig. 9, in the comparative example 1, the magnetic sensor is arranged between the air-core coil and the magnetic body (extended region of the inner circumferential surface of the air-core coil). The example 1 and the comparative example 1 only differ in the position of the magnetic sensor, and other configurations and members are the same.

[0047] The examples 2 has the same configuration as the second embodiment (Figs. 4 and 5). Meanwhile, as illustrated in Fig. 10, in the comparative example 1, the magnetic sensor is arranged in the outer circumference of the magnetic body including the protruding portion (extended region of the inner circumferential surface of the air-core coil). The example 2 and the comparative example 2 only differ in the position of the magnetic sensor, and other configurations and members are the same.

[0048] Eddy current losses of the magnetic sensors arranged at the positions in the examples 1 and 2 and the comparative examples 1 and 2 are acquired from the simulation of the magnetic field analysis. The magnetic field analysis for the example 1 and the comparative example 1 are performed under the condition of 30 A of current and 163.66 mT of the magnetic flux density ΔB . In addition, the magnetic field analysis for the example 2 and the comparative example 2 are performed under the condition of 30 A of the current and 224.52 mT of the magnetic flux density ΔB . The analysis result for the example 1 and the comparative example 1 are indicated in Table 1, and the analysis result for the example 2 and the comparative example 2 are indicated in Table 2. Note that a, b, and c in Table 2 respectively indicate the magnetic sensor 3a, 3b, and 3c in Figs. 4 and 10.

[Table 1]

	Example 1	Comparative Example 1
Eddy Current Loss (W)	0.32	9.64

[Table 2]

	Example 2			Comparative Example 2		
	a	b	c	a	b	c
Eddy Current Loss (W)	0.22	0.21	0.23	10.25	10.13	8.93

[0049] As indicated in Table 1, it is observed that the example 1 can significantly reduce eddy current loss down to 1/30 or less compared to the comparative example 1. In addition, it is observed that the example 2 can significantly reduce eddy current loss in each three magnetic sensors down to 1/40 or less compared to the comparative example 2. That is, it is observed that, by providing the magnetic sensor in the outer circumference of the magnetic body other than the extended region of the inner circumferential surface of the air-core coil 1, eddy current loss can be significantly reduced.

(Other Embodiment)

[0050] In the present specification, although embodiments according to the present invention have been described, said embodiments are only provided as examples and are intended to limit the scope of invention. Above-described embodiments can be implemented in other various forms, and various omissions, replacements, and modifications may be performed without departing from the scope of invention. Embodiments and modifications thereof are included in the scope and abstract of the invention, and are included in the invention described in the claims of the invention and equivalent ranges thereto.

[0051] In the present embodiment, although the magnetic sensor is integrally molded and fixed with the magnetic body 2 by resins, it is not limited thereto. For example, only the magnetic body 2 may be molded by resins, a holding portion for the magnetic sensor may be formed by resins at the time of molding, and the magnetic sensor 3 may be held by the holding portion.

[0052] In the present embodiment, although the reactor 10 includes the temperature sensor between the air-core coil 1, any sensors may be provided as long as the sensor can shorten the distance between the air-core coil 1 and can

improve the detection accuracy of the state of the reactor 10.

[0053] In the second embodiment, although three magnetic sensors 3 are all arranged in the outer circumference of the magnetic body 2 other than the extended region of the inner circumference surface of the air-core coil 1 orthogonal to the winding axial direction, when a plurality of the magnetic sensors 3 are provide in the reactor 10, at least one magnetic sensor 1 may be arranged in the outer circumference of the magnetic body 2 other than the extended region of the inner circumference surface of the air-core coil 1 orthogonal to the winding axial direction.

REFERENCE SIGN

[0054]

10: reactor
1: air-core coil
1a, 1b, 1c: air-core coil
2: magnetic body
21: protruding portion
22: plate-shape magnetic body
3: magnetic sensor
3a, 3b, 3c: magnetic sensor
4: casing
100: reactor
101: air-core coil
102: magnetic body
103: magnetic sensor

Claims

1. A reactor comprising:

an air-core coil formed by winding a conductive member in a cylindrical shape;
a magnetic body arranged to face an inner circumferential surface that is a hollow portion of the air-core coil orthogonal to a winding axial direction; and
a magnetic sensor formed by winding the conductive member to detect a magnetic state of the reactor, wherein the magnetic sensor is wound around an outer circumference of the magnetic body other than an extended region of the inner circumferential surface of the air-core coil.

2. The reactor according to claim 1, wherein the magnetic body includes a protruding portion extending from a surface facing the air-core coil toward the air-core coil.

3. The reactor according to claim 1 or 2, wherein a cross-sectional area of the conductive member forming the magnetic sensor is smaller than a cross-sectional area of the conductive member forming the air-core coil.

4. The reactor according to any one of claims 1 to 3, further comprising a sensor to detect a state of the reactor, wherein:

a plurality of the air-core coils is provided,
the plurality of the air-core coils is arranged side by side so that the winding axial directions become parallel to each other,
the magnetic sensor is arranged between the air-core coils, and
the sensor is arranged between the plurality of the air-core coils.

5. The reactor according to any one of claims 1 to 4, wherein the magnetic sensor is integrally molded and fixed with the magnetic body by resins.

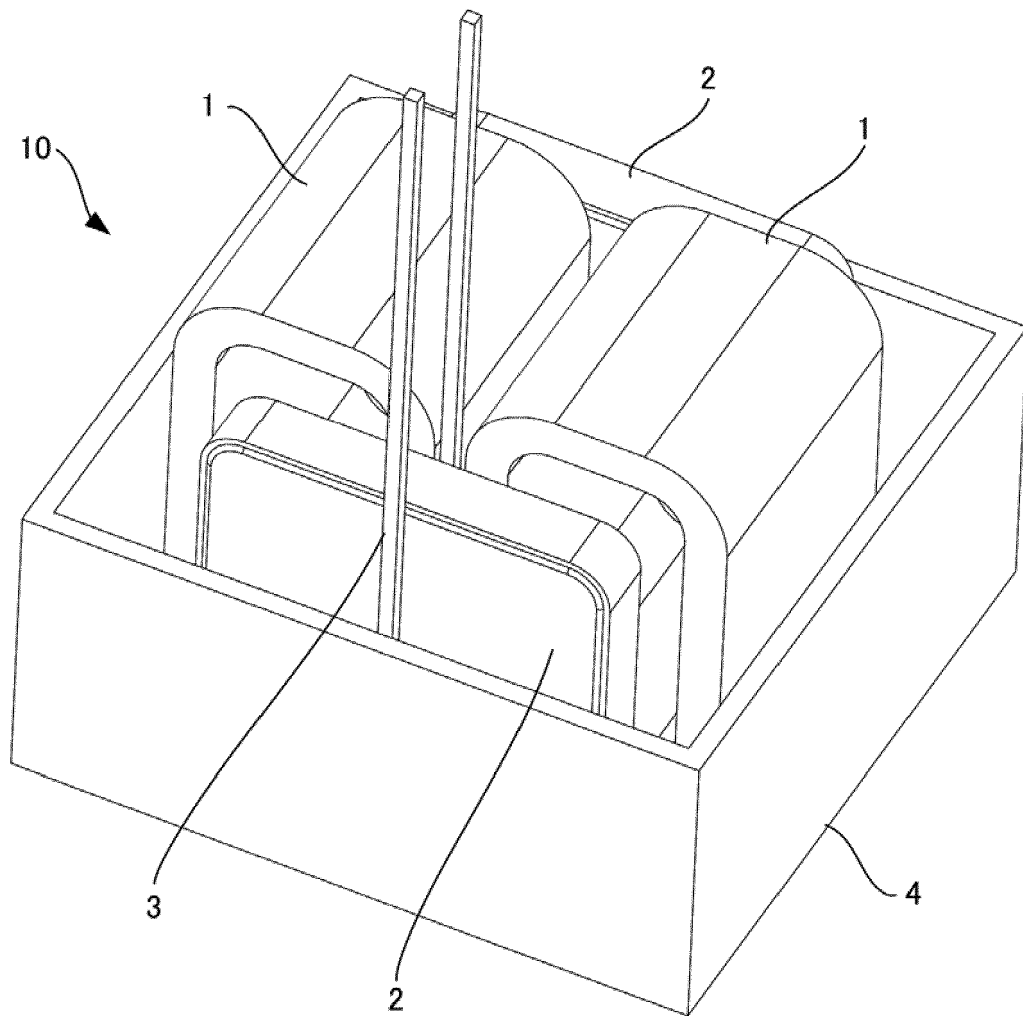


Fig. 1

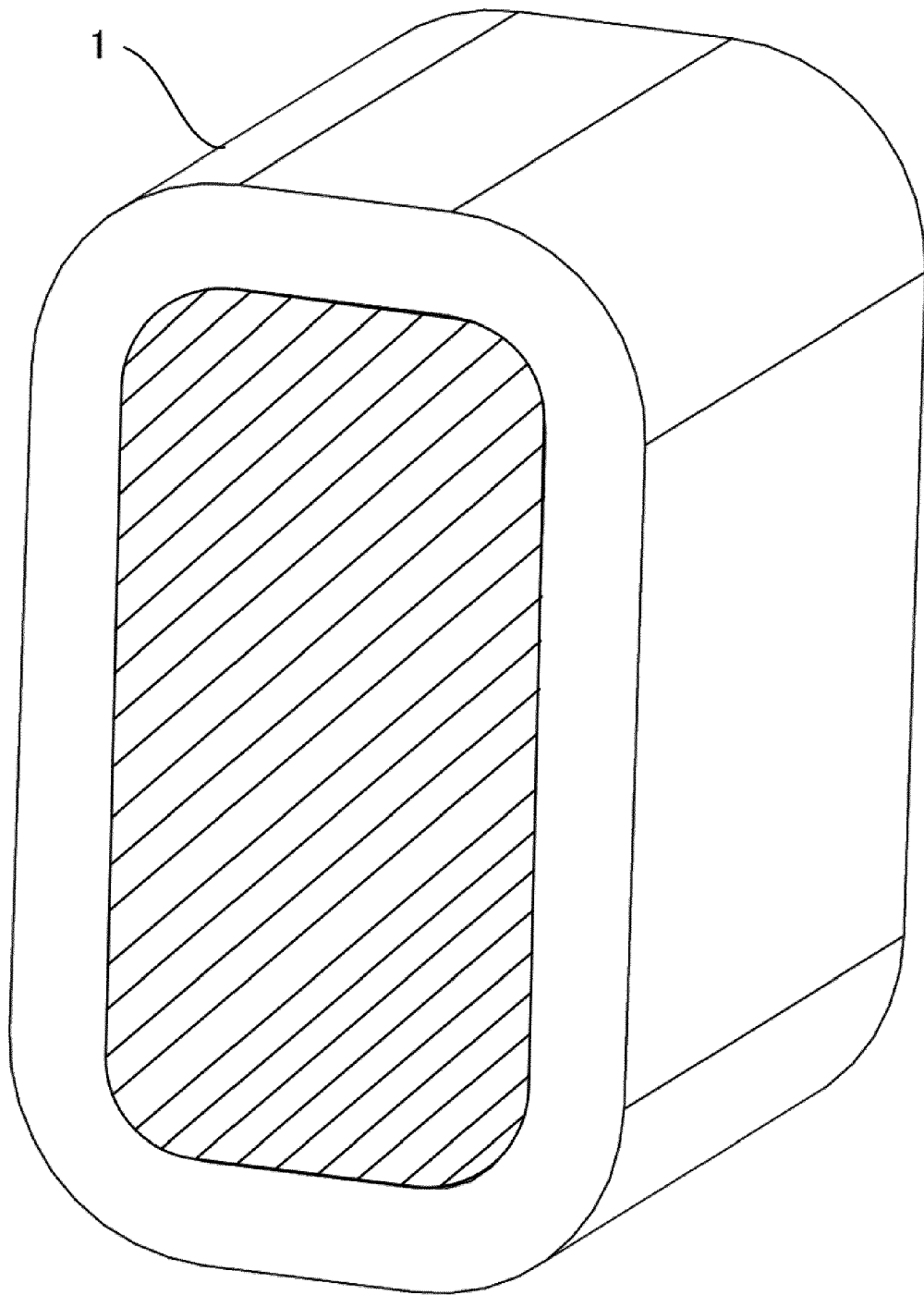


Fig. 2

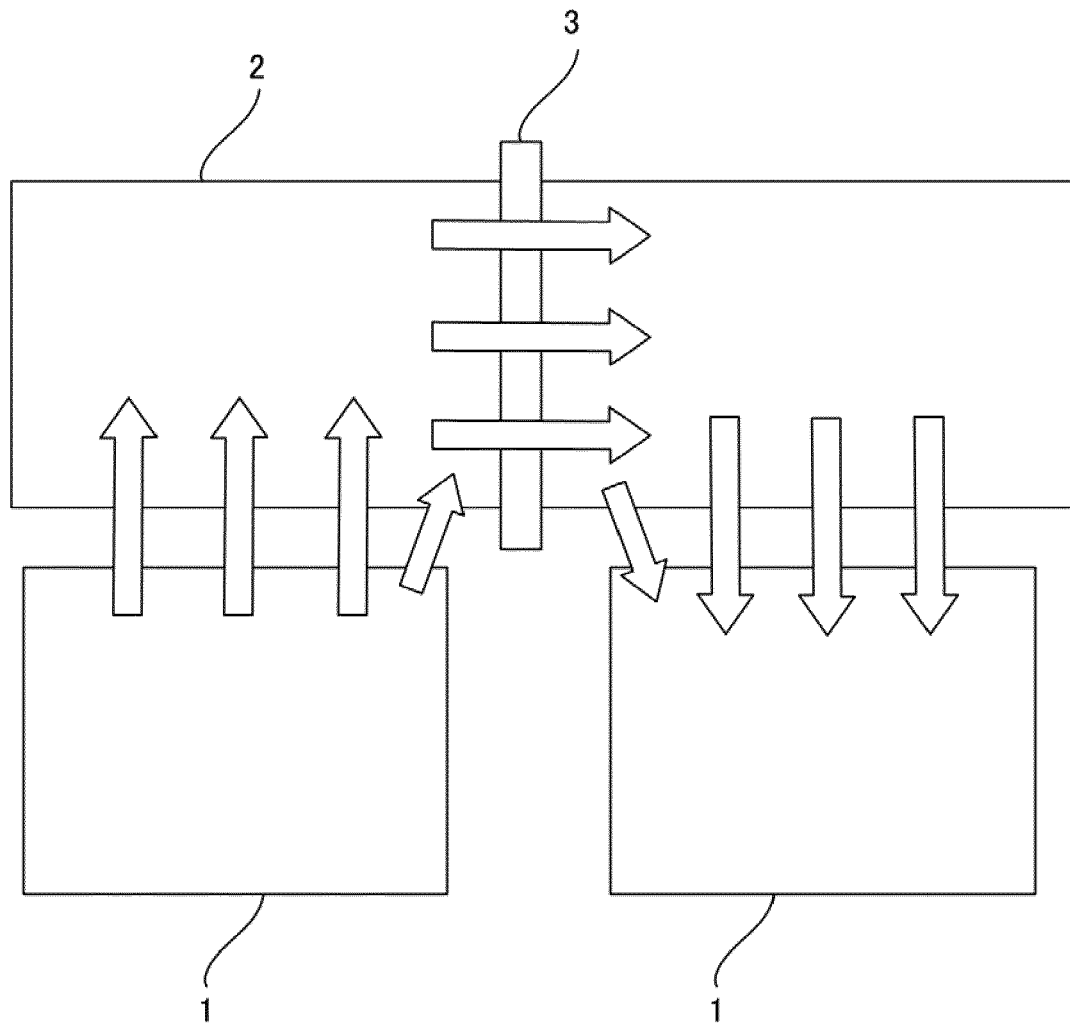


Fig. 3

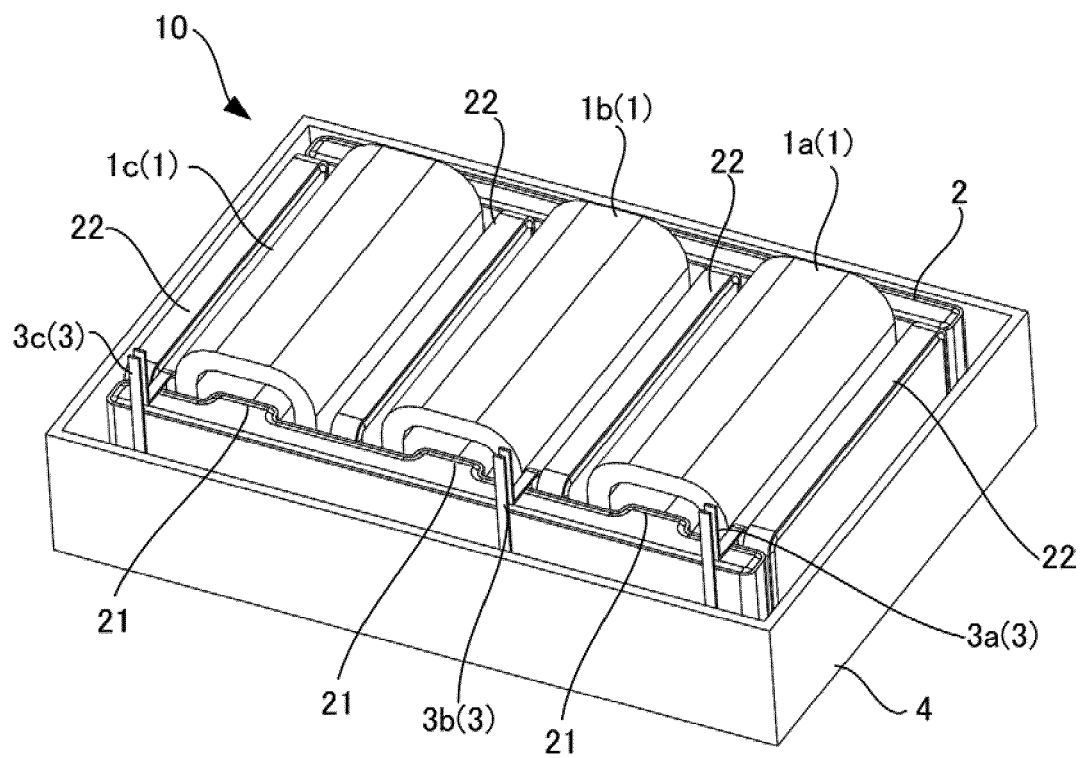


Fig. 4

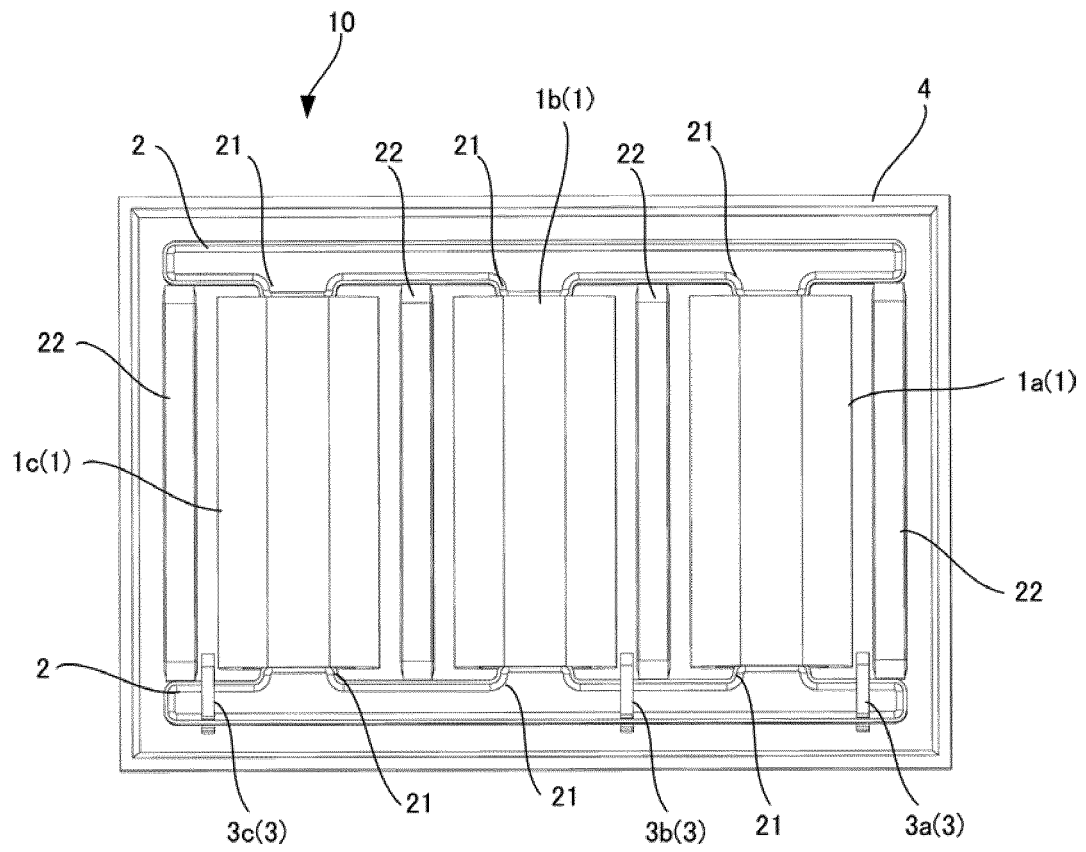


Fig. 5

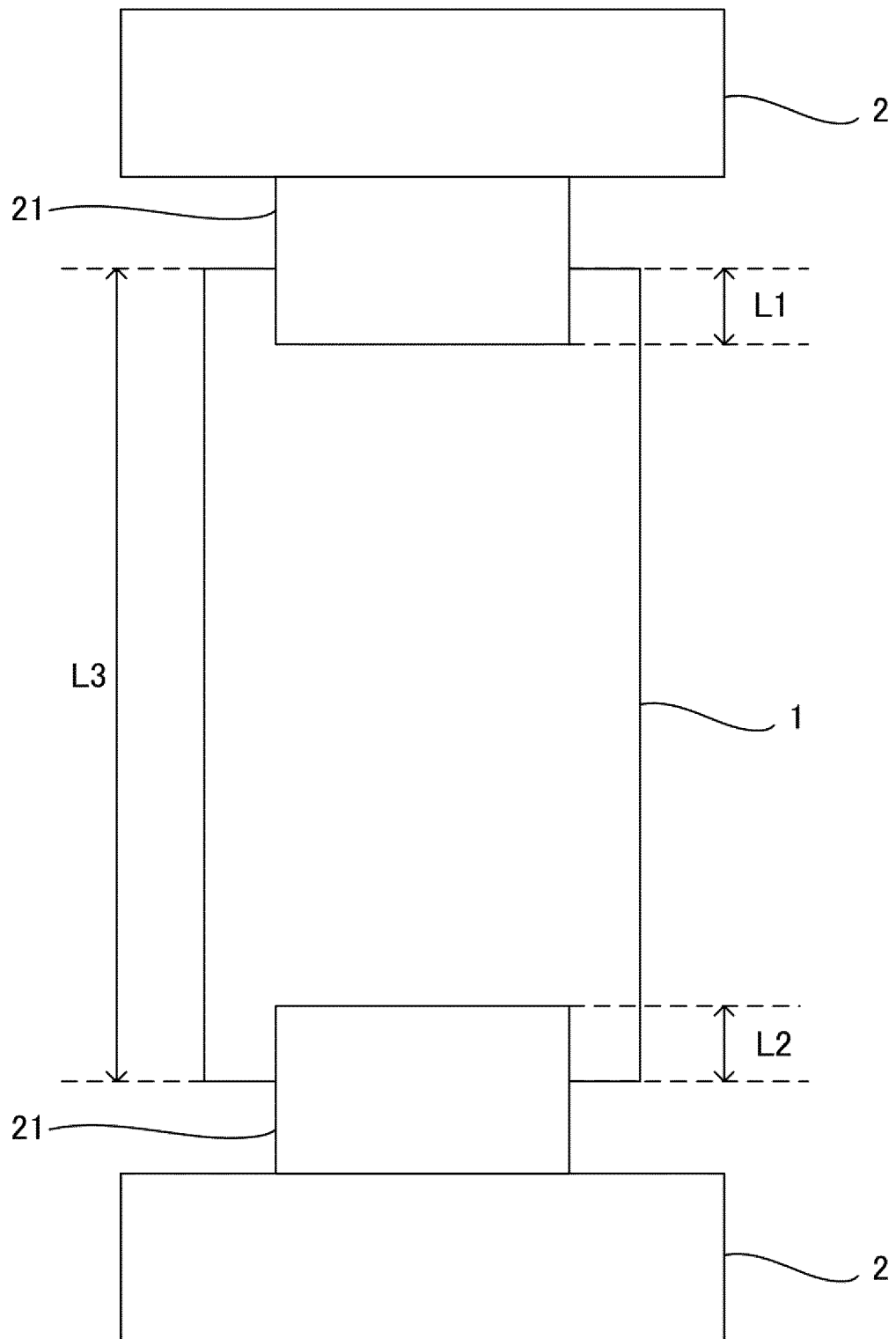


Fig. 6

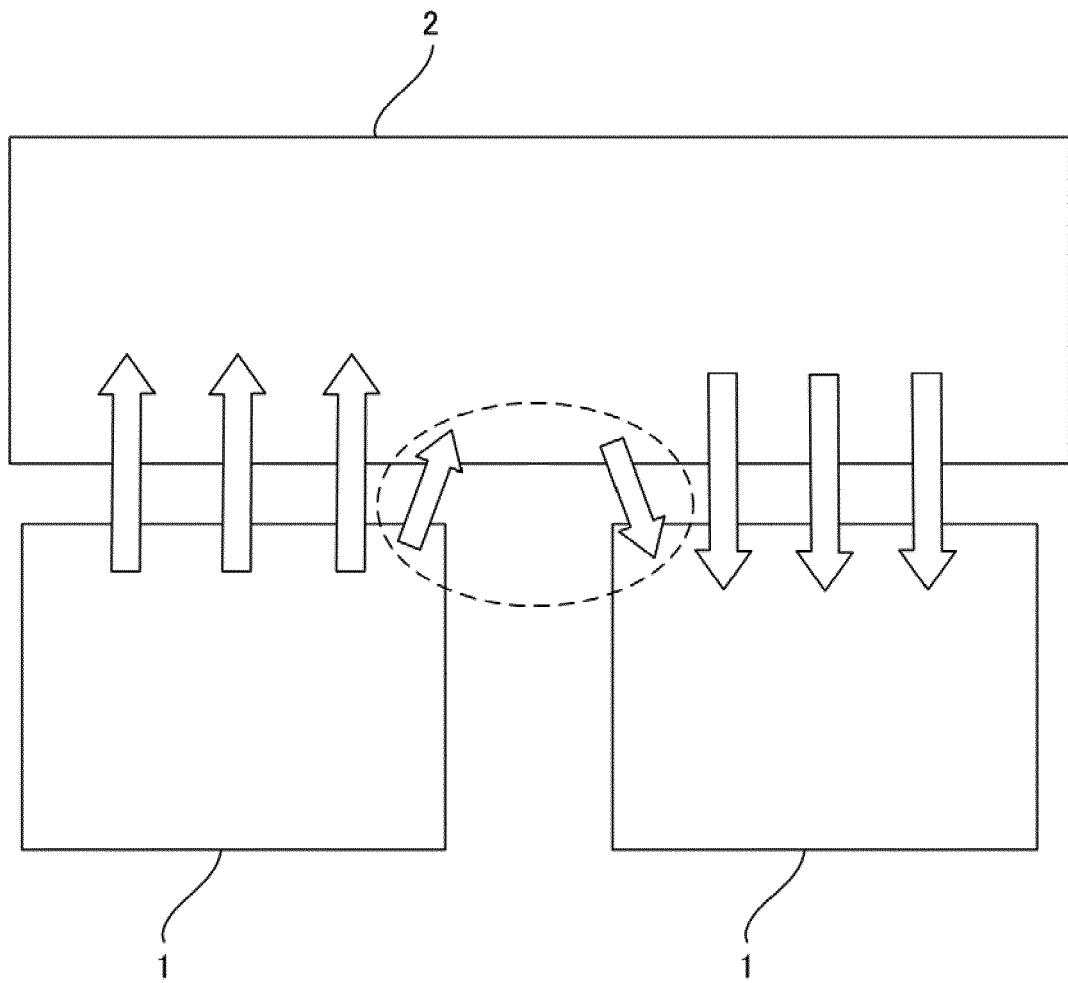


Fig. 7

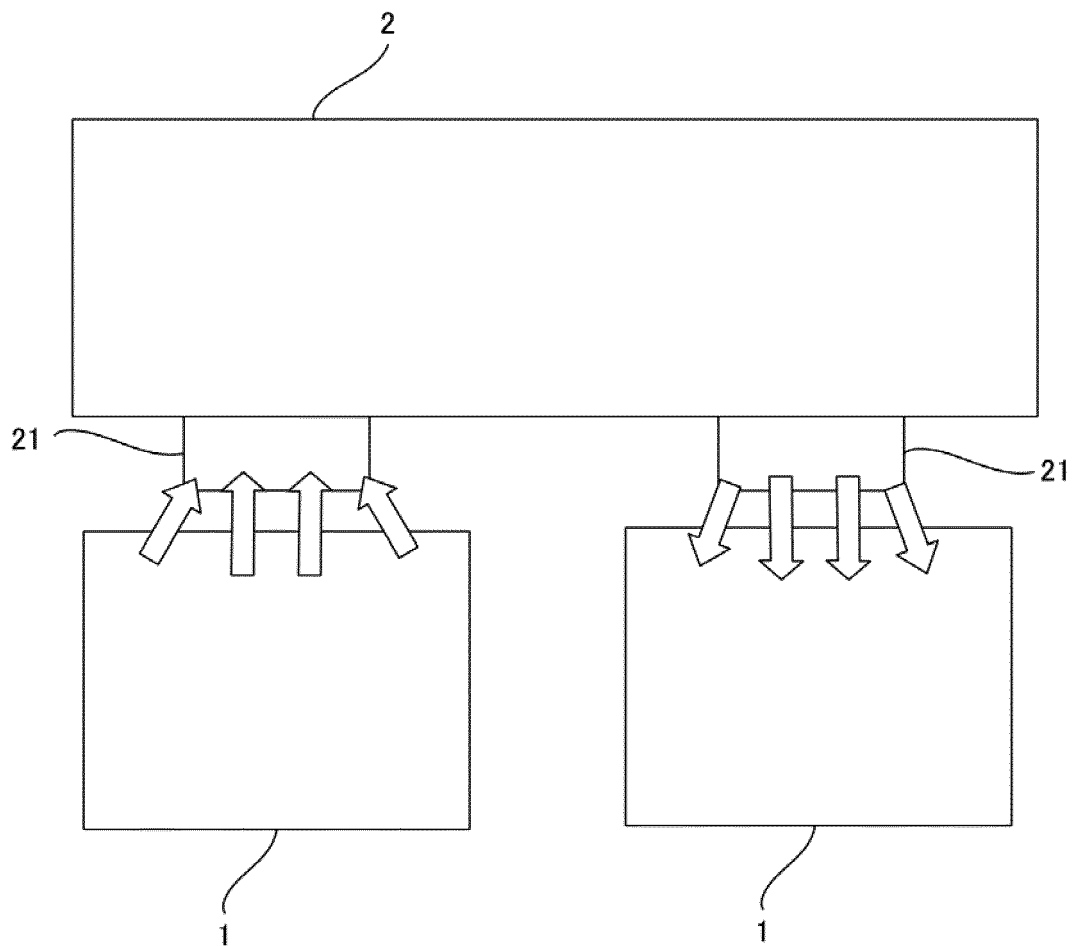


Fig. 8

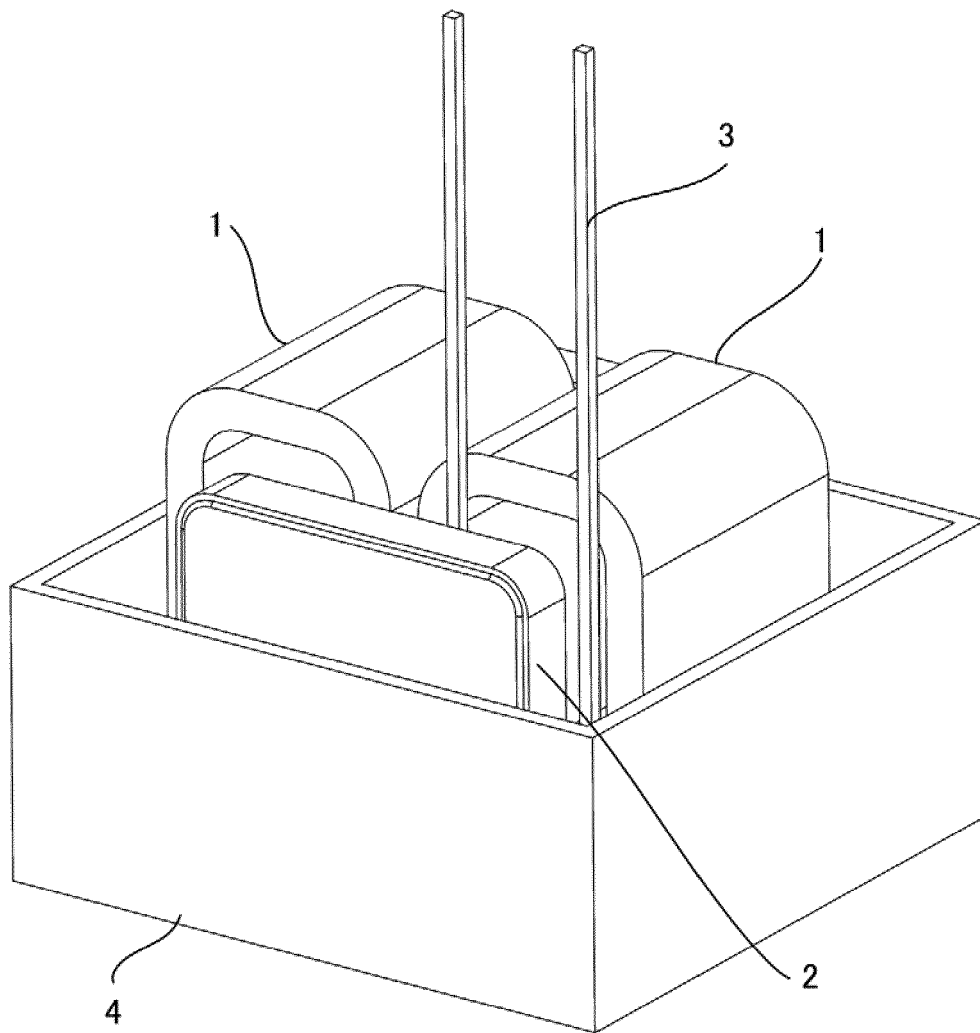


Fig. 9

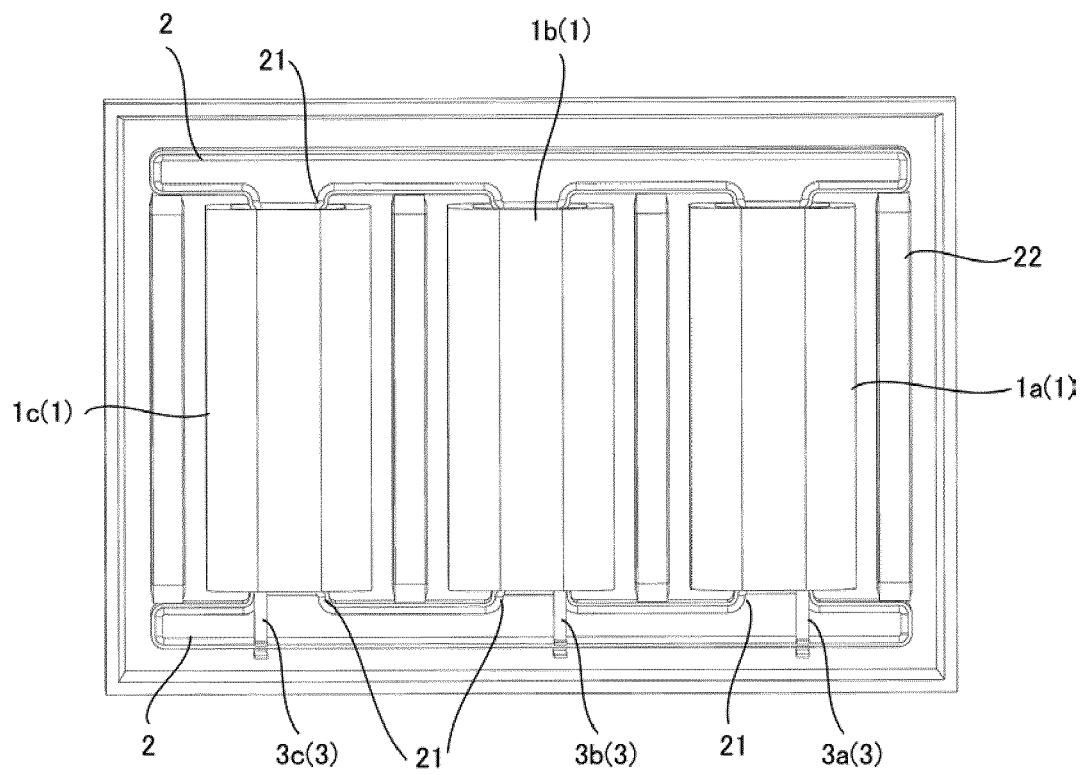


Fig. 10

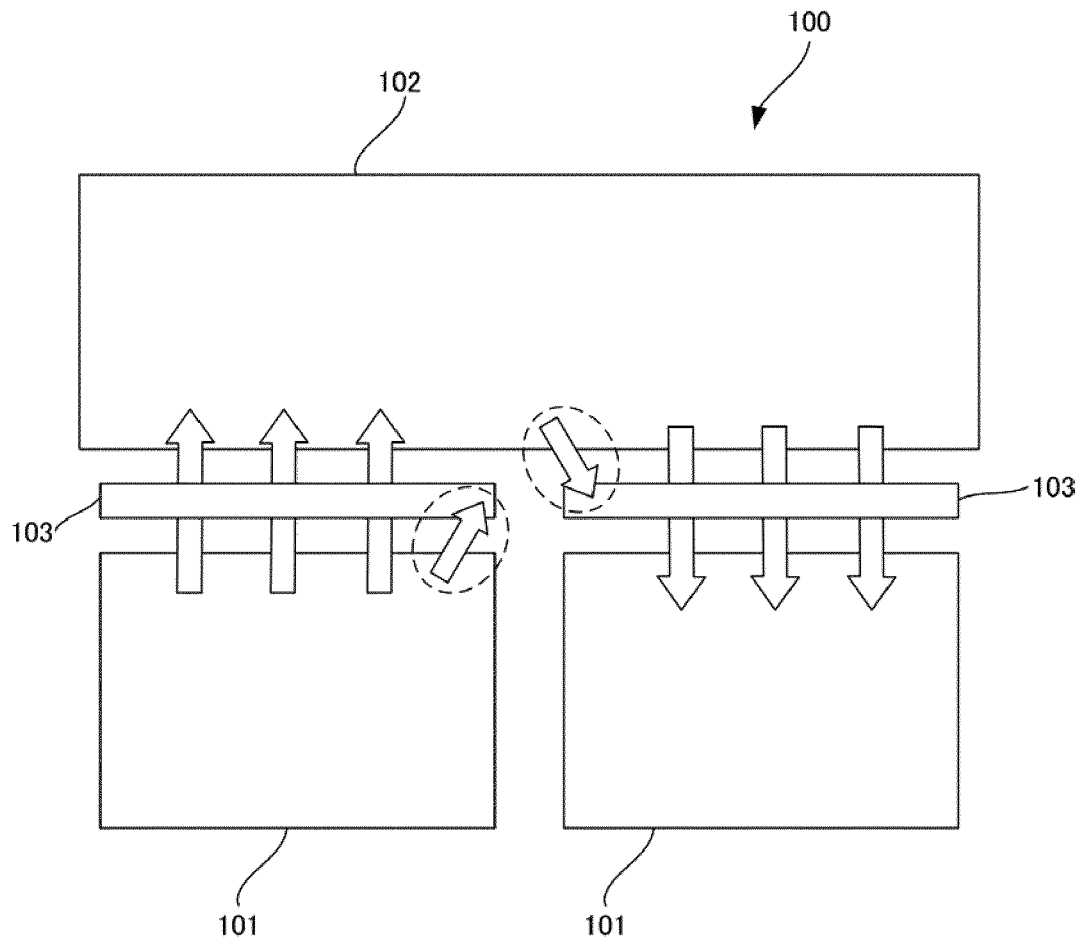


Fig. 11



EUROPEAN SEARCH REPORT

Application Number

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EPO FORM 1503 03.82 (P04C01)

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	CN 206 602 023 U (ZHUHAI JISEN ELECTRICAL APPLIANCES CO LTD) 31 October 2017 (2017-10-31) * the whole document *	1-5	INV. H01F27/40 H01F37/00
A	JP 2013 098302 A (SUMITOMO ELECTRIC INDUSTRIES; AUTO NETWORK GIJUTSU KENKYUSHO ET AL.) 20 May 2013 (2013-05-20)	1-5	
A	US 2013/049751 A1 (HAMBERGER PETER [AT] ET AL) 28 February 2013 (2013-02-28) * abstract; figures 1,2 * * page 2, paragraph 34 - page 3, paragraph 45 *	1-5	
A	US 2018/330866 A1 (TAKADA TAKASHI [JP] ET AL) 15 November 2018 (2018-11-15) * abstract; figures 1-4 * * page 9, paragraphs 79,80 *	1-5	
A	JP 2018 206907 A (TAMURA SEISAKUSHO KK) 27 December 2018 (2018-12-27) * abstract * * page 5, paragraph 26 - page 7, paragraph 39 * * page 12, paragraph 76 * * figures 1-5 *	1-5	TECHNICAL FIELDS SEARCHED (IPC) H01F
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 4 May 2022	Examiner Kardinal, Ingrid
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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ON EUROPEAN PATENT APPLICATION NO.**

EP 21 20 9181

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

04-05-2022

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 206602023 U	31-10-2017	NONE	
JP 2013098302 A	20-05-2013	NONE	
US 2013049751 A1	28-02-2013	AU 2010350863 A1	08-11-2012
		BR 112012026073 A2	28-06-2016
		CA 2800551 A1	20-10-2011
		CN 102985838 A	20-03-2013
		EP 2558875 A1	20-02-2013
		HR P20140422 T1	06-06-2014
		KR 20130021386 A	05-03-2013
		RU 2012143740 A	20-05-2014
		UA 104373 C2	27-01-2014
		US 2013049751 A1	28-02-2013
		WO 2011127969 A1	20-10-2011
US 2018330866 A1	15-11-2018	CN 108369858 A	03-08-2018
		JP 6418454 B2	07-11-2018
		JP 2017108025 A	15-06-2017
		US 2018330866 A1	15-11-2018
		WO 2017099026 A1	15-06-2017
JP 2018206907 A	27-12-2018	NONE	

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2021040330 A [0001]