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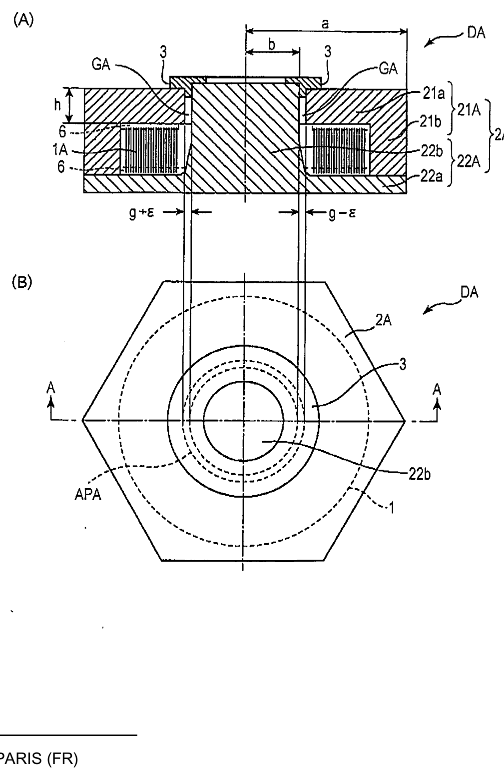
(54) **REACTOR**

(57) This reactor (DA) comprises: a coil (1A); an upper core member (21A) and a lower core member (22A) that encase the coil (1A); and a convex part core member (22b) that is positioned at the core of the coil (1A). The coil (1A) is configured by coiling a band-shaped conductor member such that the latitudinal direction of the conductor member follows the axial direction of the coil (1A). The one interior surface, of the upper core member (21A), that faces one of the end parts of the coil (1A) in the axial direction thereof, and the other interior surface, of the lower core member (22A), that faces the other of the end parts of the coil (1A) in the axial direction, are parallel in a region that at least covers the one of the end parts and the other of the end parts of the coil (1A). One of the end parts of the convex part core member (22b) is positioned within an aperture part (APA), which is formed upon the upper core member (21A), with a gap (GA) left between the circumference face of the one of the end parts and the circumference face of the aperture part (APA). The reactor (DA) thus provides a reactor that has comparatively high inductance, with low levels of loss and noise.

FIG. 1



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Description

Technical Field

[0001] The present invention relates to a reactor suitable for use in, for example, an electrical circuit and an electronic circuit.

Background Art

[0002] Reactors are passive elements employing windings, and for example, are used in various electrical circuits and electronic circuits such as for prevention of harmonic current in a power factor improvement circuit, smoothing of current pulsation in a current source inverter and chopper control, and a step-up of direct-current voltage in a converter.

[0003] From a viewpoint of reduction in environmental load, solar batteries have recently been introduced which can directly convert light energy into electric power without emitting carbon dioxide by utilizing a photovoltaic effect. For example, power generation systems using solar batteries have been introduced for residential use. Such a solar battery power generation system includes, for example, a solar battery module that converts solar energy into electric power, a power conditioner that converts direct-current power generated by the solar battery module into alternating-current power for the purpose of system interconnection, and a power distribution board that distributes the alternating-current power converted by the power conditioner to sites in houses and electric power companies. In the power conditioner, a reactor is typically employed.

[0004] From the viewpoint of reduction in the environmental load, hybrid cars and electric cars (hereinafter generically referred to as "environment-responsive cars") which can reduce emissions of carbon dioxide have been researched and developed, and have been becoming popular. Such environment-responsive cars use a booster circuit in a drive control system for a drive motor in order to enhance operating efficiency of the drive motor. In the booster circuit, a reactor is typically incorporated.

[0005] Fig. 21 includes structural views of reactors of the related art. Fig. 21(A) illustrates a reactor disclosed in PTL 1, and Fig. 21(B) illustrates a reactor disclosed in PTL 2.

[0006] A reactor for the power conditioner in the above-described solar power generation system is disclosed in, for example, PTL 1. As illustrated in Fig. 21(A), a reactor PDA disclosed in PTL 1 includes an annular core 201 formed by two opposing core yokes and a plurality of core legs provided between the core yokes. The core yokes have projections projecting toward the core legs, and gaps are formed between the core legs and the core yokes. Each of the core legs is formed by an integral core block. A ratio A/B of a length A of the projections of the core yokes and an average length B of the magnetic legs in a magnetic path direction is within the range of 0.3 to 8.0, and a coil 202 is wound around the core legs (see Fig. 3 of PTL 1). PTL 1 describes that, since the ratio A/B is optimized in the reactor thus structured, it is possible to obtain a high-efficiency reactor in which the increase in copper loss due to leakage flux from the gaps is suppressed, and that a power conditioner having high power conversion efficiency can be produced.

[0007] A reactor for the booster circuit in the drive control system is disclosed in, for example, PTL 2. As illustrated in Fig. 21(B), a reactor PDB disclosed in PTL 2 includes a coil 301, an inner core 302 provided on an inner side of the coil 301, an outer core 303 provided on an outer side of the coil 301, and end cores 304 and 304 provided at opposite ends of the coil 301. The inner core 302 includes gap materials 302a and core pieces 302b. At least one of the gap materials 302a is formed of a high thermal conductivity material having a thermal conductivity of 100 W/m · K or more at 25°C. PTL 2 describes that heat radiation performance of the core pieces 302b can be improved by the high thermal conductivity gap material 302a in the reactor thus structured.

[0008] The reactors for these purposes are required not only to have high efficiency as in PTL 1 and heat radiation efficiency as in PTL 2, but also to have a comparatively high inductance with low levels of noise and loss. In particular, since the power conditioner of the solar power generation system is frequently installed indoors, noise reduction is important for a reactor used in the power conditioner. As measures against noise, when the reactor is operated at high frequency, for example, so that noise is above an audible band of about 18 kHz or more, loss is increased by the high frequency. Hence, the above- described loss reduction is important.

Citation List

Patent Literature

[0009]

PTL 1: Japanese Unexamined Patent Application Publication No. 2008-186972

PTL 2: Japanese Unexamined Patent Application Publication No. 2008-021948

Summary of Invention

[0010] The present invention has been made in view of the above-described circumstances, and an object of the invention is to provide a reactor that has comparatively high inductance with low levels of loss and noise.

[0011] A reactor according to the present invention includes a first core section that encases a coil formed by coiling a band-shaped conductor member such that a width direction thereof follows an axial direction, and a second core section provided in a core portion of the coil.

Interior surfaces of the first core section facing both end parts of the coil are parallel in a region that at least covers the end parts of the coil, and one end part of the second core section is positioned within an aperture part provided in the first core section, with a gap left between a circumference face of the one end part and a circumference face of the aperture part. For this reason, the reactor of the present invention can have comparatively high inductance with low levels of loss and noise.

[0012] The above and further objects, features, and advantages of the present invention will become apparent from the following detailed description with reference to the attached drawings.

Brief Description of Drawings

[0013]

[Fig. 1] Fig. 1 includes structural views of a reactor according to a first embodiment.

[Fig. 2] Fig. 2 explains the relationship between a width W and a thickness t of a conductor member that forms a coil in the reactor of the first embodiment.

[Fig. 3] Fig. 3 explains the relationship between a winding structure of the coil and eddy current loss.

[Fig. 4] Fig. 4 is a graph showing the relationship between a frequency f and loss in the reactor according to the winding structure of the coil.

[Fig. 5] Fig. 5 explains vibration and noise in the reactor of the first embodiment.

[Fig. 6] Fig. 6 shows a magnetic field to magnetic flux density characteristic of a core used in the reactor of the first embodiment.

[Fig. 7] Fig. 7 illustrates lines of magnetic flux in the reactor of the first embodiment.

[Fig. 8] Fig. 8 is a cross-sectional structural view of a reactor according to a second embodiment.

[Fig. 9] Fig. 9 illustrates lines of magnetic flux in the reactor of the second embodiment.

[Fig. 10] Fig. 10 illustrates a comparison between the lines of magnetic flux in the reactor of the first embodiment and the lines of magnetic flux in the reactor of the second embodiment.

[Fig. 11] Fig. 11 is a cross-sectional structural view of a reactor according to a third embodiment.

[Fig. 12] Fig. 12 illustrates lines of magnetic flux in the reactor of the third embodiment.

[Fig. 13] Fig. 13 includes structural views of a reactor and a mount member in a modification of the third embodiment.

[Fig. 14] Fig. 14 is a cross-sectional structural view of a reactor according to a fourth embodiment.

[Fig. 15] Fig. 15 illustrates lines of magnetic flux in the reactor of the fourth embodiment.

[Fig. 16] Fig. 16 shows current to inductance characteristics of the reactors according to the first to fourth embodiments.

[Fig. 17] Fig. 17 is a cross-sectional structural view of a reactor according to a fifth embodiment.

[Fig. 18] Fig. 18 is a cross-sectional structural view of a reactor according to a sixth embodiment.

[Fig. 19] Fig. 19 is a cross-sectional structural view of a reactor according to a seventh embodiment.

[Fig. 20] Fig. 20 illustrates equivalent circuits when the reactors of the embodiments are diverted to transformers.

[Fig. 21] Fig. 21 includes structural views of reactors of the related art.

[Fig. 22] Fig. 22 illustrates the deflection factor of the reactors of the related art.

Description of Embodiments

[0014] An embodiment of the present invention will be described below with reference to the drawings. In the drawings, structures denoted by like reference numerals refer to like structures, and descriptions thereof are skipped appropriately. In this description, when the structures are generically mentioned, they will be represented by reference numerals whose appendixes are omitted. When the structures are individually mentioned, they will be represented by the reference numerals with the appendixes.

[First Embodiment]

[0015] Fig. 1 includes structural views of a reactor according to a first embodiment. Fig. 1(A) is a longitudinal sectional view including a center axis of a coil 1A, taken along the center axis, and Fig. 1(B) is a top plan view, as viewed in a direction of the center axis. In Fig. 1(B), line A-A is a section line of the longitudinal sectional view of Fig. 1(A). Fig. 2 explains the relationship between a width W and a thickness t of a conductor member that forms the coil in the reactor of the first embodiment. Fig. 3 explains the relationship between a winding structure of the coil and eddy current loss. Fig. 3(A) illustrates a case of a flat-wise winding structure, and Fig. 3(B) illustrates a case of an edge-wise winding structure. Fig. 4 is a graph showing the relationship between a frequency f and loss in the reactor according to the winding structure of the coil. Fig. 5 explains vibration and noise in the reactor of the first embodiment.

[0016] The reactor according to the first embodiment includes a coil, a first core section that encases the coil, and a second core section provided in a core portion of the coil. The coil is formed by coiling a band-shaped conductor member such that a width direction of the conductor member follows an axial direction of the coil. One interior surface of the first core section, which faces one end part of the coil in the axial direction, and the other interior surface of the first core section, which faces the other end part of the coil in the axial direction, are parallel in a region that at least covers the one end part and the other end part of the coil, and one end part of the second core section is positioned in an aperture part provided in the first core section with a gap left between a circumference face of the one end part and a circumference face of the aperture part.

[0017] For example, as illustrated in Fig. 1, a reactor DA according to the first embodiment thus structured includes a coil 1A, a core member 2A, and a gap member 3.

[0018] For example, the core member 2A is formed of a material that is isotropic magnetically (e.g., in magnetic permeability), and includes an upper core member 21A and a lower core member 22A. The upper core member 21A includes a platelike upper end core member 21a having a predetermined thickness and shaped like a polygon, a hexagon in the example of Fig. 1, and a cylindrical side wall core member 21b having a predetermined thickness and extending from an outer peripheral edge of the upper end core member 21a in a substantially perpendicular direction. A transverse section of the cylindrical side wall core member 21b taken in a direction perpendicular to an axial direction is hexagonal in outline (outer shape) because the upper end core member 21a is hexagonal, in the example of Fig. 1. Further, since the cylindrical coil 1A having a pancake structure is positioned in the cylinder of the side wall core member 21b, as will be described below, a circular aperture is provided in the hexagon. The upper end core member 21a has an aperture part APA serving as a through opening. In the example of Fig. 1, the aperture part APA is a circular hole having a predetermined diameter and centered on the center (geometrical center of gravity) of the upper end core member 21a. The lower core member 22A includes a platelike lower end core member 22a having a predetermined thickness and shaped like the same polygon as the upper end core member 21a, a hexagon in the example of Fig. 1, and a convex part core member 22b provided on one principal surface of the lower end core member 22a. In the example of Fig. 1, the convex part core member 22b is shaped like a column centered on the center (geometrical center of gravity) of the lower end core member 22a and having a predetermined outer diameter. The outer diameter gradually increases from a middle portion in the axial direction toward the lower end core member 22a, and a circumference face of the column is tapered. While the convex part core member 22b is solid in the example of Fig. 1, it may have an internal cavity. Further, heat radiation performance of the reactor may be enhanced by passing a predetermined fluid, such as air or water, through the cavity.

[0019] The core member 2A is formed by coupling (connecting) an end of the side wall core member 21b of the upper core member 21A thus structured to a peripheral edge of the lower end core member 22a of the lower core member 22A in a substantially gapless manner. A space for receiving the coil 1A is thereby formed between the upper end core member 21a and the lower end core member 22a and between the side wall core member 21b and the convex part core member 22b. When the upper core member 21A and the lower core member 22A are coupled in this way, a distal end part of the convex part core member 22b is inserted in the aperture part APA of the upper end core member 21a, and is positioned in the aperture part APA with a gap GA left between a circumference face (outer circumference face) of the distal end part of the convex part core member 22b and a circumference face (inner circumference face) of the aperture part APA. That is, the diameter of the aperture part APA is larger than the diameter of the convex part core member 22b. In the example of Fig. 1, the distal end part of the convex part core member 22b slightly protrudes outward from an outer surface of the upper end core member 21b.

[0020] The upper end core member 21a and the side wall core member 21b in the upper core member 21A and the lower end core member 22a in the lower core member 22A correspond to an example of the above-described first core section containing the coil 1A, and the convex part core member 22b in the lower core member 22A corresponds to an example of the above-described second core section positioned in the core portion of the coil 1A.

[0021] The first core section (the upper end core member 21a, the side wall core member 21b, and the lower end core member 22a in the example of Fig. 1) serves to reduce magnetic flux leaking outside, and the maximum relative magnetic permeability thereof is designed, for example, on the basis of the allowed magnitude of leakage flux of the reactor DA that is defined by the specifications. Preferably, the maximum relative magnetic permeability of the first core section is, for example, about 100 or more for the reactor DA suitable for use in a power conditioner of a solar battery power generation system.

[0022] The maximum relative magnetic permeability of the second core section (the convex part core member 22b in the example of Fig. 1) is designed, for example, on the basis of the magnitude of inductance, which is required for the reactor DA, specified by the specifications because the maximum relative magnetic permeability has an influence on the inductance of the reactor DA. The power conditioner of the solar battery power generation system requires stability of an inductance characteristic in that the change in inductance is small with respect to the change in current so that operation is stably performed even when the current changes. Since the change in current is steep when the inductance is comparatively low, it is better that the inductance is comparatively high. However, as the inductance increases, the size of the reactor DA increases. As described above, particularly in residential use of the power conditioner of the solar battery power generation system, the average value of current flowing through the reactor DA is about 20 A, and is about 30 A at most. Hence, there is no need to respond to a wide range of currents. That is, since a current more than or equal to a predetermined range does not flow in the power conditioner of the solar battery power generation system, stability of the inductance characteristic is not required for large currents, For this reason, it is preferable that the inductance should be about 1 mH around the current value of 20 A, in consideration of the balance therebetween, and the maximum relative magnetic permeability of the second core section is set in consideration of a gap effect and so on.

[0023] Preferably, from viewpoints of ease of realization of a desired magnetic characteristic and ease of molding in a desired shape, for example, the core member 2A is molded from soft magnetic powder alone or a mixture of soft magnetic powder and nonmagnetic power. For example, the mixture ratio of soft magnetic powder and nonmagnetic powder can be comparatively easily adjusted. By appropriately adjusting the mixture ratio, a desired magnetic characteristic of the core member 2A can be realized easily. Further, since the core member 2A is formed of soft magnetic powder alone or the mixture of soft magnetic powder and nonmagnetic powder, it can be molded in various shapes, and can be easily molded in a desired shape. From a viewpoint of cost reduction, the upper core member 21A and the lower core member 22A are preferably formed of the same raw material.

[0024] This soft magnetic power is ferromagnetic metal powder, and more specifically, examples of the soft magnetic powder are pure iron powder, iron-base alloy powder (e.g., an Fe-Al alloy, an Fe-Si alloy, sendust, or a permalloy), amorphous powder, and iron powder whose surface is covered with an electrical insulating coating such as a phosphorylated coating. These soft magnetic powders can be produced, for example, by a method of performing microparticulation using atomization or a method of reducing iron oxide after pulverization.

[0025] The upper core member 21A and the lower core member 22A are members that have a predetermined magnetic flux density to relative magnetic permeability characteristic and that are molded from a mixture of iron powder serving as soft magnetic powder and resin serving as nonmagnetic powder using a known common method to have a predetermined density. The magnetic flux density to relative magnetic permeability characteristic refers to the change in relative magnetic permeability with respect to the change in magnetic flux density.

[0026] While the upper end core member 21a and the side wall core member 21b in the upper core member 21A are integrally formed in the example of Fig. 1, they may be separately formed and then coupled (connected) to each other. Similarly, while the lower end core member 22a and the convex part core member 22b in the lower core member 22A are integrally formed in the example of Fig. 1, they may be separately formed and then coupled (connected) to each other. While the core member 2A is divided into the upper core member 21A and the lower core member 22A in the example of Fig. 1, it may be arbitrarily divided into members.

[0027] The coil 1A is formed by coiling a long conductor member in a predetermined number of turns, and is energized to generate a magnetic field. In this embodiment, the coil 1A is formed by coiling a band-shaped conductor member such that the width direction of the conductor member follows the axial direction of the coil 1A. The coil 1A is positioned in the above-described space formed between the upper end core member 21a and the lower end core member 22a and between the side wall core member 21b and the convex part core member 22b, and the convex part core member 22b is positioned in the core portion of the coil 1A to penetrate through the coil 1A. In this way, the reactor DA of this embodiment is a so-called pot type reactor in which the cored coil 1A is received in the internal space of the core member 2A. Further, in the reactor DA of the embodiment, one interior surface of the upper end core member 21a, which faces one end part of the coil 1A in the axial direction, and the other interior surface of the lower end core portion 22a, which faces the other end part of the coil 1A in the axial direction, are parallel to each other in a region that at least covers the one end part and the other end part of the coil 1A.

[0028] The term "band-shaped" refers to a shape such that the width W is larger than the thickness t, as illustrated in Fig. 2. That is, the width W and the thickness t have a relationship that W > t (W/t > 1). In this way, the coil 1A of the embodiment has a so-called flat-wise winding structure.

[0029] Here, a description will be given of eddy current losses of the reactor DA including the coil 1A having the flat-wise winding structure in which the conductor member is coiled to have layers stacked in the radial direction (Figs. 1 and 3(A)), and a reactor DH including a coil 1H having an edge-wise winding structure in which a conductor member is coiled to have layers stacked in the axial direction (Fig. 3(B)).

[0030] In general, when a coil is energized, eddy current occurs in a plane (orthogonal plane) perpendicular to lines of magnetic force because the coil is formed of a conductor, and this causes loss. When the magnetic flux density is the same, the magnitude of the eddy current is proportional to the area intersecting the lines of magnetic force, that is, the area of a continuous plane perpendicular to the lines of magnetic force. Since the lines of magnetic force extend in the axial direction in the coil, as illustrated in Figs. 3(A) and 3(B), the eddy current is proportional to the area of a plane of the conductor of the coil in the radial direction orthogonal to the axial direction.

[0031] For this reason, in the edge-wise winding structure, as illustrated in Fig. 3(B), the area of the conductor member in the radial direction is large, eddy current is likely to occur, and loss caused by the eddy current is more dominant than loss caused by electrical resistance. Therefore, in the edge-wise winding structure, as illustrated in Fig. 4, the loss depends on the frequency of energizing current and increases as the frequency increases.

[0032] In contrast, the flat-wise winding structure of the reactor DA of the embodiment, as illustrated in Figs. 3(A) and 1, the area of the conductor member in the radial direction is small and eddy current is unlikely to occur, but the area in the axial direction is large. Therefore, in the flat-wise winding structure, as illustrated in Fig. 4, little eddy current occurs, and loss is caused only by the electrical resistance and is substantially constant regardless of the frequency of energizing current.

[0033] Further, while the conductor member is stacked in the axial direction in the edge-wise winding structure, as illustrated in Fig. 3(B), the conductor member is continuous in a state in which the width direction nearly coincides with the axial direction in the flat-wise winding structure, as illustrated in Figs. 3(A) and 1. Hence, heat generated in the coil is more effectively transferred to the core in the flat-wise winding structure than in the edge-wise winding structure.

[0034] The reactor DA thus including the coil 1A having the flat-wise winding structure is superior to the reactor DH including the coil 1H having the edge-wise winding structure in terms of loss and heat transfer.

[0035] From this viewpoint of heat transfer, a gap formed between the coil 1A and the first core section (upper end core member 21a, side wall core member 21b, and lower end core member 22a) in the reactor DA may be filled with a heat transfer material 6 that comparatively properly transfers heat, as shown by broken lines in Fig. 1. In the reactor DA thus structured, heat produced in the coil 1A can be transferred via the heat transfer material to the first core section surrounding the coil 1A, and this can improve heat radiation performance. As the heat transfer material, a polymeric material having comparatively high thermal conductivity (polymeric material having comparatively high conductivity) can be given as an example. For example, the polymeric material is epoxy resin having high adhesiveness. For example, the heat transfer material may be an insulating material such as BN ceramic (boron nitride ceramic), and filling may be performed with a compound. Such a heat transfer material can also improve insulation performance.

[0036] In this embodiment, the conductor member is band-shaped in the flat-wise winding structure, as described above. That is, as illustrated in Fig. 2(A), the reactor DA is formed of the conductor member forming the coil 1A such that the conductor member has a rectangular cross section in which the width W is greater than the thickness t (the length of the conductor member in the radial direction).

[0037] Thus, as illustrated in Fig. 2(B), the area in the radial direction is smaller than in a reactor formed by a conductor member having a rectangular cross section in which the thickness t is greater than the width W. As a result, eddy current loss can be reduced for a reason similar to the above-described reason why the coil 1A having the flat-wise winding structure is superior to the coil DH having the edge-wise winding structure in terms of loss. Particularly when a ratio t/W of the width W to the thickness t in the conductor member is 1/10 or less ($t/W \leq 1/10$, $10t \leq W$), the occurrence of eddy current loss can be significantly reduced.

[0038] In the reactor DA of the embodiment, as described above, one interior surface of the first core section (upper end core member 21a), which faces one end part of the coil 1A in the axial direction, and the other interior surface of the first core section (lower end core member 22a), which faces the other end part of the coil 1A in the axial direction, are parallel to each other in the region that at least covers the one end part and the other end part of the coil 1A.

[0039] That is, even when such a condition of the coil 1A (the flat-wise winding structure is adopted and the width W is greater than the thickness t) is set, the lines of magnetic flux (lines of magnetic force) passing through the coil 1A are not substantially parallel to the axial direction unless the reactor DA is structured such that the upper end lower interior wall surfaces (upper and lower wall surfaces) of the first core section, which face the upper and lower end faces of the coil 1A, are parallel in the region that at least covers the end parts of the coil 1A.

[0040] For example, when a distance at a position on the innermost peripheral side of the coil 1A (innermost peripheral position), of distances between the upper wall surface and the lower wall surface of the first core section, is taken as L1, a distance at a position on the outermost peripheral side of the coil 1A (outermost peripheral position) is taken as L2, and the average value of the distances from the innermost peripheral position to the outermost peripheral position is taken as L3, a value (L1-L2)/L3 obtained by dividing a difference between the distance L1 between the upper wall surface and the lower wall surface of the first core section at the innermost peripheral position of the coil 1A and the distance L2 between the upper wall surface and the lower wall surface of the first core section at the outermost peripheral position of the coil 1A by the average value L3 is defined as parallelism. The average value L3 refers to an average value of distances at a plurality of positions spaced at a predetermined interval between the innermost peripheral position and the outermost peripheral position.

[0041] When such parallelism is defined, the present inventor verified the distribution of lines of magnetic flux while variously changing the parallelism. For example, when the parallelism is 1/100, the lines of magnetic flux passing through the coil 1 are parallel to the axial direction. In contrast, when the parallelism is -1/10 or 1/10, the lines of magnetic flux passing through the coil 1 are not parallel to the axial direction. According to this verification, it is preferable that the absolute value of the parallelism should be 1/50 or less in order for the lines of magnetic flux passing through the coil 1A to be parallel.

[0042] Unillustrated terminals are connected to opposite ends of the coil 1A to feed power from the outside to the coil 1A. These terminals lead to the outside via the first core section, for example, via through holes provided in the upper end core member 21a.

[0043] The gap member 3 is a member to be inserted in the gap GA having a predetermined distance (gap length) formed between the circumference face (outer circumference face) of the distal end part of the convex part core member 22b and the circumference face (inner circumference face) of the aperture part APA. The gap member 3 maintains the gap length, and fixes the upper end core member 21a of the upper core member 21A and the convex part core member 22b of the lower core member 22A. In the example of Fig. 1, the gap member 3 includes a cap portion doughnut-shaped in plan view, and a cylindrical gap portion hanging from a lower surface of the cap portion to be inserted in the gap GA. A longitudinal section of the gap member 3 taken perpendicularly to the circumferential direction is substantially T-shaped. Such a gap member 3 is formed of epoxy resin or alumina for example. By adjusting the gap length, the change in inductance within a desired current range can be controlled.

[0044] In the reactor DA having this structure, product-to-product variations in gap length (differences among individual reactors) are reduced, compared with reactors of the related art, for example, the reactors PDA and PDB having structures illustrated in Figs. 21(A) and 21(B). As a result, in the reactor DA of the first embodiment, product-to-product variations in inductance can be reduced.

[0045] That is, in the reactors PDA and PDB having the conventional structures illustrated in Figs. 21(A) and 21(B), the gap length changes according to the manufacturing accuracy of the material to be inserted in the gaps and an application condition of adhesive. When the change value is taken as ε_n and the designed value is taken as g, $\Sigma(g+\varepsilon_n)$ (were Σ sums values of n from 1 to the gap number). In the reactors PDA and PDB having the conventional structures, comparatively large product-to-product variations in inductance are caused when the change value ε varies. Accordingly, if the gap number is decreased to increase the accuracy of the gap length in the reactors PDA and PDB having the conventional structures, the gap length needs to be increased to obtain equivalent characteristics. For this reason, leakage flux from the gap increases, and the leakage flux passes through the conductor of the coil, so that eddy current loss increases. As a result, the efficiency of the reactor is reduced.

[0046] In contrast, in the reactor DA of the embodiment, the convex part core member 22b is inserted in the aperture part APA of the upper end core member 21a, and the gap GA is formed between the circumference face (outer circumference face) of the distal end part of the convex part core member 22b and the circumference face (inner circumference face) of the aperture part APA. For this reason, even when the center (axial center) of the convex part core member 22b and the center of the aperture part APA are not aligned (they are not coaxial), but are misaligned with each other, the gap length is balanced out on both sides of the center (axial center) $(g+\varepsilon, g-\varepsilon)$, as illustrated in Fig. 1. Therefore, the average of the annular gap GA over the entire circumference is constant at $((g+\varepsilon)+(g-\varepsilon))/2 = g$. As a result, the inductance of the reactor DA of the embodiment is constant. For example, when the core member 2A is formed by compacting iron powder, product-to-product variations in inductance are reduced or are not caused because manufacturing accuracies of the diameter of the aperture part APA of the upper end core member 21a and the diameter of the convex part core member 22b nearly coincide with the accuracy of a mold.

[0047] Since the mechanical structural rigidity in the radial direction of the reactor DA thus structured is higher than, for example, that of the reactors PDA and PDB having the conventional structures of Figs. 21(A) and 21(B), the reactor DA thus structured can reduce vibration and noise.

[0048] That is, for example, in the reactor PDB having the conventional structure of Fig. 21(B), in a case in which the radius (outer radius) and the thickness of the outer core 303 are taken as a and h, respectively, and the radius of the inner core 302 is taken as b, when the load due to the in-gap attractive fore is p, the maximum center displacement amount u is $\alpha \times p \times a^4/(E \times h^8) = [\alpha \times a^4/h^3] \times (p/E)$, and is proportional to (p/E)(in the expression, E represents the Young's modulus and α is a deflection factor).

[0049] In contrast, in the reactor DA of the embodiment, as illustrated in Figs. 1(A) and 5, in a case in which the radius (outer radius) and the thickness of the upper end core member 21a (core member 2A) are taken as a and h, respectively, and the radius of the convex part core member 22b is taken as b, when the load due to the in-gap attractive fore is p, the maximum center displacement amount u is $\{1-v+(1+v) \times a^2/b^2\} \times \{p \times b^3/(Ex(a^2-b^2))\} = [\{1-v+(1+v) \times a^2/b^2\} \times \{b^3/(a^2-b^2)\}] \times (p/E)$, and is proportional to (p/E)(in the expression, E represents the Young's modulus and ν represents the Poisson's ratio). In general, the Poisson's ratio ν is about 0.5 for liquid and about 0.3 for solid.

[0050] Therefore, when the reactor PDB having the conventional structure of Fig. 21(B) and the reactor DA of the embodiment are formed of the same material such that inductances thereof are equivalent, the displacement amounts of the reactors can be compared by comparing these proportionality coefficients ($[\alpha x a^4/h^3]$, $[\{1-\nu+(1+\nu) \times a^2/b^2] \times \{b^3/(a^2-b^2)\}]$. Accordingly, when a:b:h is 2:1:0.5 as a typical shape, the deflection factor α is 0.1 to 0.35, and the Poisson's ratio ν is 0.3, the proportionality coefficient is estimated at 13 to 45 in the reactor PDB having the conventional structure of Fig. 21(B). In contrast, the proportionality coefficient is 1.5 in the reactor DA of the embodiment. For this reason, the proportionality coefficient of the reactor DA of the embodiment is about 3 to 12% of the proportionality coefficient of the reactor PDB having the conventional structure of Fig. 21 (B). In the reactor DA of the embodiment, the displacement amount is smaller than in the reactor PDB having the conventional structure of Fig. 21(B). As a result, noise is reduced.

[0051] While the deflection factor α is 0.1 to 0.35 in the above, this is because the deflection factor α varies according to an edge fixing condition. The deflection factor

α is considered to range from a value in simple edge support illustrated in Fig. 22(A) to a value in clumped edge support illustrated in Fig. 22(B). Fig. 22(C) shows a characteristic curve of the deflection factor α with respect to an inner-outer diameter ratio b/a. As is seen from Fig. 22(C), when a:b = 2:1, $0.1 < \alpha < 0.35$.

[0052] While it is assumed above that the center (axial center) of the convex part core member 22b and the center of the aperture part APA are aligned with each other, even if they are not aligned (are not concentric), but are misaligned with each other, noise is reduced in the reactor DA of the embodiment.

[0053] That is, when I represents the current and L represents the inductance, an attractive force F acting on the core with the gap when the gap length g changes by a small amount Δg is $I^2/2\ \partial L/\partial g$. In the reactors PDA and PDB having the structures illustrated in Figs. 21(A) and 21(B), even if the gap member is formed of a hard material in order to accurately manage the gap length, the surface of the core and the surface of the gap member opposing the surface of the core are not completely flat in the order of several micrometers, but have irregularities. For this reason, the core and the gap member cannot be combined in a state in which the surface of the core and the surface of the gap member opposing the surface of the core are completely flat, and they need to be brought into tight contact with each other by a comparatively soft plugging material such as adhesive. The gap length is changed by loosening and rattling due to this soft plugging material, and this causes vibration and noise. Particularly when a reactor for a power conditioner of a solar power generation system or a reactor for an environment-responsive car is used at high frequency, vibration of the core is about several micrometers.

[0054] In contrast, in the reactor DA of the embodiment, as described above, the convex part core member 22b is inserted in the aperture part APA of the upper end core member 21a and the gap GA is formed between the circumference face (outer circumference face) at the distal end part of the convex part core member 22b and the circumference face (inner circumference face) of the aperture part APA. Hence, the average of the annular gap GA is constant over the entire circumference, and therefore, there is no need to accurately manage the gap length of the gap GA. Therefore, the above-described soft plugging material is unnecessary, and noise resulting from gap management during assembly in the reactors PDA and PDB having the conventional structures is reduced or does not occur.

[0055] This reactor DA of the embodiment can be produced through the following steps. First, a band-shaped (ribbon-shaped) long conductor member insulatively covered with an insulating material and having a predetermined thickness t is prepared, and the conductor member is wound around a convex part core member 22b in a predetermined number of turns. Alternatively, the conductor member is wound in a predetermined number of turns from a position apart a predetermined radius from the center (axial center) to form an air-cored coil, and the air-cored coil is mounted on a lower core member 22A such that the convex part core member 22b is positioned in a core portion of the air-cored coil. Thus, a coil 1A having a pancake structure is formed which has the convex part core member 22b in the center portion (core portion) and which is formed by coiling the band-shaped long conductor member, which is superposed with the insulating material disposed therebetween, in a predetermined number of turns. Next, an end of a side wall core member 21b of an upper core member 21A is coupled (connected) to a peripheral edge of a lower end core member 22a of the lower core member 22A in a substantially gapless manner. Then, a gap member 3 is mounted in a gap GA. Thus, a reactor DA illustrated in Fig. 1 is produced.

[0056] As described above, in the reactor DA having the above-described structure, the coil 1A is formed by coiling the band-shaped conductor member such that the width direction of the conductor member follows the axial direction of the coil 1A, and the inner wall surface of the upper end core member 21a in the upper core member 21A, which faces one end part of the coil 1A in the axial direction, and the inner wall surface of the lower end core member 22a in the lower core member 22A, which faces the other end part of the coil 1A in the axial direction, are parallel to each other in the region that at least covers the one end part and the other end part of the coil 1A. For this reason, since the width direction of the band-shaped conductor member extends in the direction of magnetic flux in the coil 1A, the reactor DA thus structured can reduce eddy current loss, as described above.

[0057] The reactor DA having the above-described structure is a so-called pot type reactor including the upper core member 21A and the lower core member 22A that encase the coil 1A, and the coil 1A has the convex part core member 22b of the lower core member 22A in its core portion. Hence, the reactor DA can have comparatively high inductance.

[0058] In the reactor DA having the above-described structure, one end part (distal end part) of the convex part core member 22b in the lower core member 22A is positioned in the aperture part APA in the upper end core member 21a of the upper core member 21A with the gap GA left between the circumference face of the one end part and the circumference face of the aperture part APA. Hence, the change in inductance within a desired current range can be controlled by adjusting the distance of the gap GA (gap length). For example, when the aperture part APA is circular and the one end part (distal end part) of the convex part core member 22b is also circular, the gap length is defined by the difference between the diameter (inner diameter) of the aperture part APA and the diameter (outer diameter) of the one end part of the convex part core member 22b. Hence, the reactor DA thus structured can suppress the change in the gap length due to misalignment between the center of the aperture part APA and the center of the one end part of the convex part core member 22b. For this reason, the reactor DA thus structured can reduce product-to-product variations in gap length (differences among individual reactors). As a result, the reactor DA thus structured can also reduce product-to-product variations in inductance.

[0059] In general, both electromagnetic attractive force and magnetostrictive expansion are produced in the radial direction in the gap GA. Since the reactor DA thus structured has high mechanical structural rigidity in the radial direction, it can reduce vibration and noise. As measures against noise, even when the reactor is operated at high frequency, for example, so that noise is above an audible band of about 18 kHz or more, since the eddy current loss is reduced, as described above, loss can also be reduced.

[0060] Therefore, the reactor DA thus structured can have comparatively high inductance with low levels of loss and noise.

[0061] Fig. 7 shows a magnetic-field analysis result when low inductance is obtained in a large current range in the reactor DA thus structured. In this magnetic field analysis, compacted iron powder having a magnetic characteristic shown by a solid line in Fig. 6 was used in the core member 2A. In Fig. 6, a magnetic characteristic of a directional electromagnetic steel sheet is also shown by a broken line. Fig. 6 shows a magnetic field to magnetic flux density characteristic of the core used in the reactor of the first embodiment. In Fig. 6, the horizontal axis indicates the magnetic field expressed in the unit of A/m, and the vertical axis indicates the magnetic flux density expressed in the unit of T. Fig. 7 illustrates lines of magnetic flux in the reactor of the first embodiment.

[0062] As is understood from Fig. 7, most lines of magnetic flux circulate in the core member 2A, and are partly flow out from the upper core member 21A, pass through the coil 1A, and flow into the lower core member 22A. Since the above-described structure is adopted in the embodiment, these lines of magnetic flux nearly extend in the width direction of the conductor member of the coil 1A, and this reduces eddy current generated by the lines of magnetic flux.

[0063] While the magnetic permeability of the compacted iron powder is lower than that of the directional electromagnetic steel sheet, when the reactor D adopts the structure of the embodiment and below-described structures, it can obtain inductance performances suitable for various kinds applications, for example, as illustrated in Fig. 16 described below.

[0064] Next, another embodiment will be described.

[Second Embodiment]

[0065] Fig. 8 is a cross-sectional structural view of a reactor according to a second embodiment. Fig. 9 illustrates lines of magnetic flux in the reactor of the second embodiment. Fig. 10 illustrates a comparison between the lines of magnetic flux in the reactor of the first embodiment and the lines of magnetic flux in the reactor of the second embodiment.

[0066] In a reactor DB of the second embodiment, the other end part of the second core section is coupled to the first core section, and the first core section further includes a projection extending from a peripheral edge that forms the aperture part into the first core. Such a reactor DB of the second embodiment includes, for example, a coil 1A, a core member 2B, and a gap member 3, as illustrated in Fig. 8. Since the coil 1A and the gap member 3 in the reactor DB of the second embodiment are similar to the coil 1A and the gap member 3 in the reactor DA of the first embodiment, descriptions thereof are skipped.

[0067] For example, the core member 2B is formed of a material that is isotropic magnetically (e.g., in magnetic permeability), and includes an upper core member 21B and a lower core member 22A. Since the lower core member 22A in the reactor DB of the second embodiment is similar to the lower core member 22A in the reactor DA of the first embodiment, a description thereof is skipped.

[0068] The upper core member 21B includes a plate-like upper end core member 21a having a predetermined thickness and shaped like a polygon, for example, a hexagon, and a cylindrical side wall core member 21b having a predetermined thickness and extending from an outer peripheral edge of the upper end core member 21a in a substantially perpendicular direction. The upper end core member 21a has an aperture part APA serving as a through aperture. Since the upper end core member 21a and the side wall core member 21b in the reactor DB of the second embodiment are similar to the upper end core member 21a and the side wall core member 21b in the reactor DA of the first embodiment, descriptions thereof are skipped. In the second embodiment, the upper core member 21B further includes a projection 21c extending from a peripheral edge that forms the aperture part APA into the first core.

[0069] In the reactor DB of the second embodiment having such a structure, even when the reactor DB is designed to have high inductance in a comparatively small current range by increasing the number of turns of the coil 1A, as illustrated in Fig. 9, the direction of lines of magnetic flux passing through the coil 1A can be made close to a direction parallel to the axial direction of the coil 1A, and eddy current loss can be reduced for the above-described reason. This can be easily understood with reference to Fig. 10 that shows a comparison with the reactor DA of the first embodiment, That is, when the number of turns of the coil 1A is increased to obtain a higher inductance, lines of magnetic flux passing through the coil 1A during energization are curved in the reactor DA of the first embodiment that does not include the projection 21c, as illustrated in Fig. 10(B). In contrast, in the reactor DB of the second embodiment, the direction of lines of magnetic flux passing through the coil 1A during energization can be made close to the direction parallel to the axial direction of the coil 1A, as illustrated in Fig.

10(A). For this reason, the reactor DB of the second embodiment can reduce eddy current loss more than in the case in which the projection 21c is not provided.

[0070] Next, a further embodiment will be described.

[Third Embodiment]

[0071] Fig. 11 is a cross-sectional structural view of a reactor according to a third embodiment. Fig. 12 illustrates lines of magnetic flux in the reactor of the third embodiment.

[0072] In a reactor DC according to the third embodiment, the other end part of the second core section is positioned in a second aperture part provided in the first core section with a second gap left between a circumference face of the other end part and a circumference face of the second aperture part. For example, as illustrated in Fig. 11, such a reactor DC of the third embodiment includes a coil 1A, a core member 2C, and gap members 3 and 4. Since the coil 1A and the gap member 3 in the reactor DC of the third embodiment are similar to the coil 1A and the gap member 3 in the reactor DA of the first embodiment, descriptions thereof are skipped.

[0073] For example, the core member 2C is formed of a material that is isotropic magnetically (e.g., in magnetic permeability), and includes an upper core member 21A, a lower core member 22B, and a center core member 23A. Since the upper core member 21A in the reactor DC of the third embodiment is similar to the upper core member 21A in the reactor DA of the first embodiment, a description thereof is skipped.

[0074] The lower core member 22B is similar to an upper end core member 21a in the upper core member 21A, and is a platelike member having the same polygonal shape as the shape of the upper end core member 21a, for example, a hexagonal shape. The lower core member 22B has an aperture part APB serving as a through aperture similar to an aperture part APA of the upper end core member 21a. In the example illustrated in Fig. 11, the aperture part APB is a circular hole having a predetermined diameter and centered on a center position (geometrical center of gravity) of the lower core member 22B.

[0075] The center core member 23A is a column having a predetermined outer diameter, similarly to the convex part core member 22b of the first embodiment. While the center core member 23A is solid, it may have an internal cavity. Further, heat radiation performance of the reactor may be enhanced by passing a predetermined fluid, such as air or water, through the cavity. One end part of the center core member 23A is inserted in the aperture part APA of the upper end core member 21a, and is positioned in the aperture part APA with a first gap GAA left between a circumference face (outer circumference face) of the one end part of the center core member 23A and a circumference face (inner circumference face) of the aperture part APA. The other end part of the center core member 23A is inserted in the aperture part APB of the lower core member 22B, and is positioned in the aperture part APB with a second gap GAB left between a circumference face (outer circumference face) of the other end part of the center core member 23A and a circumference face (inner circumference face) of the aperture part APB.

[0076] The upper core member 21A and the lower core member 22B correspond to an example of the first core section encasing the coil 1A, and the center core member 23A corresponds to an example of the second core section provided in the core portion of the coil 1A.

[0077] The gap member 3 is a member to be inserted in the gap GAA with a predetermined distance (gap length) formed between the circumference face (outer circumference face) of the one end part of the center core member 23A and the circumference face (inner circumference face) of the aperture part APA. The gap member 4 is a member to be inserted in the gap GAB with a predetermined distance (gap length) formed between the circumference face (outer circumference face) of the other end part of the center core member 23A and the circumference face (inner circumference face) of the aperture part APB. The gap member 3 maintains the gap length, and fixes the upper end core member 21a of the upper core member 21A and the center core member 23A. The gap member 4 maintains the gap length, and fixes the lower core member 22B and the center core member 23A. Each of the gap members 3 and 4 includes a cap portion doughnut-shaped in plan view, and a cylindrical gap portion hanging from a lower surface of the cap member to be inserted in the gap GA. A longitudinal section of the gap members 3 and 4 perpendicular to the circumferential direction is substantially T-shaped. For example, the gap members 3 and 4 are formed of epoxy resin or alumina.

[0078] The coil 1A is located in a space formed between the upper end core member 21a and the lower core member 22B and between a side wall core member 21b and the center core member 23A, and the center core member 23A is located in the core portion of the coil 1A to penetrate through the coil 1A.

[0079] As illustrated in Fig. 12(A), in the reactor DC of the third embodiment thus structured, most lines of magnetic flux circulate in the core member 2C, and partly flow out from the upper core member 21A, flow through the coil 1A, and flow into the lower core member 22. Since this embodiment adopts the above-described structure, the lines of magnetic flux extend nearly in the width direction of the conductor member of the coil 1A, and eddy current produced by the lines of magnetic flux is reduced.

[0080] Since the reactor DC of the third embodiment thus structured includes a plurality of gaps GA, that is, the first gap GAA and the second gap GAB, the gaps GA can be provided separately. For this reason, as shown by comparison of Fig. 7 and Fig. 12, the reactor DC of the third embodiment thus structured can reduce magnetic flux leaking outside more than the reactor DA of the first embodiment. As a result, the reactor DC can minimize the influence of leakage flux on peripheral devices provided around the reactor DC.

[0081] Here, a description will be given of a case in which the reactor DC of the third embodiment including the first and second gaps is mounted on a mount member. Fig. 13 includes structural views of reactors and mount members according to a modification of the third embodiment. Fig. 13(A) is an overall perspective view of a first mode of the modification, Fig. 13(B) is a cross-sectional view of the first mode of the modification, Fig. 13(C) is a bottom view of the first mode of the modification, as viewed from a mount member side, Fig. 13(D) is a schematic cross-sectional view (schematic view of Fig. 13(C)), schematically illustrating a cross-section of the first mode of the modification, and Fig. 13(E) is a schematic cross-sectional view schematically illustrating a cross section of a second mode of the modification.

[0082] In general, the reactor generates heat through various losses. When the temperature increases to high temperature, for example, the reactor is fixed in contact with a flat radiator plate formed of a good thermal conductivity metal material, which has comparatively low thermal conductivity, for the purpose of heat transfer and heat radiation. For example, the metal material is copper or an alloy thereof, iron or an alloy thereof, or aluminum and an alloy thereof. If the reactor DC of the third embodiment is mounted on a mere radiator plate shaped like a flat plate for the purpose of heat transfer and heat radiation, since the reactor DC has the second gap GAB and the radiator plate has electrical conductivity, leakage flux leaking due to the second gap GAB may cause eddy current in the radiator plate.

[0083] Accordingly, in a first mode of a modification of the third embodiment, as illustrated in Figs. 13(A) to 13 (D), a radiator plate 6A has one or a plurality of slit holes 6a in a mount surface on which a reactor DC' is to be mounted. The longitudinal direction of the slit holes 6a intersects a second gap GAB in plan view, as viewed in the axial direction of a coil 1A, and the slit holes 6a penetrate through the radiator plate 6A.

[0084] In a second and first mode, as illustrated in Fig. 13(E), a radiator plate 6B has one or a plurality of slit grooves 6b on a mount surface on which a reactor DC' is to be mounted. The longitudinal direction of the slit grooves 6b intersects a second gap GAB in the longitudinal direction in plan view, as viewed in the axial direction of a coil 1A, and the slit grooves 6b have a depth greater than or equal to the distance of the second gap GAB.

[0085] In the examples illustrated in Figs. 13(A) to (D) and 13(E), a plurality of slit holes 6a and 6b are radially arranged in the radial direction and at regular intervals in the circumferential direction on the mount surface on which the reactor DC' is to be mounted in a manner such that the longitudinal direction thereof intersects the second gap GAB.

[0086] In contrast to the reactor DC illustrated in Fig. 11, in the modification illustrated in Fig. 13, the reactor DC' does not include the gap member 3 and 4, and is fastened to the radiator plate 6A or 6B by bolts 7 via through holes provided in a core member 2C'. Further, while the overall shape of the core member 2C' is the same as that of the core member 2C, the core member 2C' is formed by two upper and lower members of the same shape.

[0087] In the reactor DC' thus structured, since the slit holes 6a are provided in the radiator plate 6A, or since the slit grooves 6b are provided in the radiator plate 6B, the flow of the above-described eddy current is prevented by the slit holes 6a or the slit grooves 6b. Therefore, the reactor DC' thus structured can radiate heat without causing any power loss and any inductance change.

[0088] Next, a further embodiment will be described.

[Fourth Embodiment]

[0089] Fig. 14 is a cross-sectional structural view of a reactor according to a fourth embodiment. Fig. 15 illustrates lines of magnetic flux in the reactor of the fourth embodiment.

[0090] In a reactor DC according to the fourth embodiment, the other end part of the second core section is provided with a third gap from the other interior surface of the first core section. For example, as illustrated in Fig. 14, such a reactor DD of the fourth embodiment includes a coil 1A, a core member 2D, and a gap member 3. Since the coil 1A and the gap member 3 in the reactor DD of the fourth embodiment are similar to the coil 1A and the gap member 3 in the reactor DA of the first embodiment, descriptions thereof are skipped.

[0091] For example, the core member 2D is formed of a material that is isotropic magnetically (e.g., in magnetic permeability), and includes an upper core member 21A, a lower core member 22C, and a center core member 23B. Since the upper core member 21A in the rector DD of the fourth embodiment is similar to the upper core member 21A. in the reactor DA of the first embodiment, a description thereof is skipped.

[0092] The lower core member 22C is a platelike member having a predetermined thickness and the same polygonal shape as the outer shape of an upper end core member 21a, for example, a hexagonal shape.

[0093] The center core member 23B is a column having a predetermined outer diameter, similarly to the convex part core member 22b in the first embodiment. While the center core member 23B is solid, it may have an internal cavity. Further, heat radiation efficiency of the reactor may be enhanced by passing a predetermined fluid, such as air or water, through the cavity. One end part of the center core member 23B is inserted in an aperture part APA of the upper end core member 21a, and is positioned in the aperture part APA with a first gap GAA left between a circumference face (outer circumference face) of the one end part of the center core member 23B and a circumference face (inner circumference face) of the aperture part APA. The other end part of the center core member 23B is provided with a third gap GAC from an interior surface of the lower core member 22C. For example, a gap member of epoxy resin or alumina (unillustrated) is inserted in the third gap GAC. A peripheral edge of the other end part of the center core member 23B may be chamfered, for example, by R-chamfering or C-chamfering. In the example illustrated in Fig. 14, the peripheral edge is subjected to R-chamfering.

[0094] The upper core member 21A and the lower core member 22C correspond to an example of the first core section encasing the coil 1A, and the center core member 23B corresponds to an example of the second core section provided in the core portion of the coil 1A.

[0095] The coil 1A is provided in a space formed between the upper end core member 21a and the lower core member 22B and between a side wall core member 21b and the center core member 23B, and the center core member 23B is provided in the core portion of the coil 1A.

[0096] In the reactor DD of the fourth embodiment having this structure, as is understood from Fig. 15(A), most lines of magnetic flux circulate in the core member 2D, and partly flow out from the upper core member 21A, pass through the coil 1A, and flow into the lower core member 22C. Since this embodiment adopts the above-described structure, the direction of the lines of magnetic flux nearly follows the width direction of a conductor member of the coil 1A, and eddy current caused by the lines of magnetic flux is reduced.

[0097] The reactor DD of the fourth embodiment thus structured includes a plurality of gaps GA, that is, the first gap GAA and the third gap GAC, and therefore, the gaps GA can be provided separately. For this reason, with reference to Fig. 7 and Fig. 15 in comparison, the reactor DC of the fourth embodiment thus structured can reduce more leakage magnetic flux leaking outside than the reactor DA of the first embodiment. As a result, the influence of leakage flux on peripheral devices provided around the reactor DD can be minimized.

[0098] Fig. 16 shows inductance characteristics of the reactors DA, DB, DC, and DD according to the first to fourth embodiments. In Fig. 16, the horizontal axis is a logarithmic scale indicating the current expressed in the unit of A, and the vertical axis indicates the inductance expressed in the unit of μH. Here, ■, O, Δ, and ◇ indicate the inductance characteristics of the reactors DA, DB, DC, and DD of the first to fourth embodiments, respectively.

[0099] As shown in Fig. 16, in the reactors DA, DC, and DD of the first, third, and fourth embodiments, the inductance hardly changes and is stable within a comparatively large current range, in the range of about 20 A to about 200 A in the example of Fig. 16. Particularly within the range of about 20 A to about 150 A, the change in inductance is smaller and the inductance is more stable, which is preferable. Further, within the range of about 20 A to about 100 A, the change in inductance is even smaller, and the inductance is even more stable, which is preferable. The reactors DA, DC, and DD of the first, third, and fourth embodiments are of a large current type.

[0100] In the reactor DB of the second embodiment, the inductance hardly changes and is stable within the range of a comparatively small current range, within the range of about 5 A to about 25 A in the example of Fig. 16. Particularly within the range of about 5 A to about 20 A, the change in inductance is smaller and the inductance is more stable, which is preferable.

[0101] Next, a further embodiment will be described.

[Fifth Embodiment]

[0102] Fig. 17 is a cross-sectional structural view of a reactor according to a fifth embodiment. While the coil 1A is a single coil having a pancake structure in the reactors DA, DB, DC, and DD of the first to fourth embodiments, a reactor DE according to the fifth embodiment uses a coil 1B formed by a plurality of sub-coils stacked in the axial direction, instead of the coil 1A in the reactors DA, DB, DC, and DD of the first to fourth embodiments. Fig. 17 illustrates the reactor DE of the fifth embodiment that employs the core member 2B in the reactor DB of the second embodiment. In the example illustrated in Fig. 17, the reactor DE of the fifth embodiment includes the coil 1B, the core member 2B, and a gap member 3. Since the core member 2B and the gap member 3 in the reactor DE of the fifth embodiment are similar to the core member 2B and the gap member 3 in the reactor DB of the second embodiment, descriptions thereof are skipped.

[0103] The coil 1B includes a plurality of sub-coils stacked in the axial direction, that is, two sub-coils 11a and 11b in the example illustrated in Fig. 17. Similarly to the coil 1A, each of the sub-coils 11a and 11b is formed by coiling a band-shaped conductor member such that the width direction of the conductor member follows the axial direction of the sub-coil 11a or 11b (coil 1B).

[0104] Next, a further embodiment will be described.

[Sixth Embodiment]

[0105] Fig. 18 is a cross-sectional structural view of a reactor according to a sixth embodiment. While the coil 1A is a single coil having a pancake structure in the reactors DA, DB, DC, and DD of the first to fourth embodiments, a reactor DF according to the sixth embodiment employs a coil 1C formed by a plurality of sub-coils stacked in the radial direction, instead of the coil 1A in the reactors DA, DB, DC, and DD of the first to fourth embodiments. Fig. 18 illustrates the reactor DF of the sixth embodiment that employs the core member 2B in the reactor DB of the second embodiment. In the example illustrated in Fig. 18, the reactor DF of the sixth embodiment includes the coil 1C, the core member 2B, and a gap member 3. Since the core member 2B and the gap member 3 in the reactor DF of the sixth embodiment are similar to the core member 2B and the gap member 3 in the reactor DB of the second embodiment, descriptions thereof are skipped.

[0106] The coil 1C includes a plurality of sub-coils stacked in the radial direction, that is, two sub-coils 12a and 12b in the example of Fig. 18. Similarly to the coil 1A, each of the sub-coils 12a and 12b is formed by coiling a band-shaped conductor member such that the width direction of the conductor member follows the axial direction of the sub-coil 12a or 12b (coil 1C). The sub-coil 12a is located on a relatively inner side, and the sub-coil 12b is located on a relatively outer side.

[0107] Next, a further embodiment will be described.

[Seventh Embodiment]

[0108] Fig. 19 is a cross-sectional structural view of a reactor according to a seventh embodiment.

[0109] While the coil 1A is a single coil having a pancake structure in the reactors DA, DB, DC, and DD according to the first to fourth embodiments, a reactor DG according to the seventh embodiment employs a coil 1D formed by coiling a plurality of band-shaped conductor members to form layers with insulating layers being disposed therebetween, instead of the coil 1A in the reactors DA, DB, DC, and DD of the first to fourth embodiments. Fig. 19 illustrates the reactor DG of the seventh embodiment that employs the core member 2B in the reactor DB of the second embodiment. In the example illustrated in Fig. 19, the reactor DG of the seventh embodiment includes the coil 1D, the core member 2B, and a gap member 3. Since the core member 2B and the gap member 3 in the reactor DG of the seventh embodiment are similar to the core member 2B and the gap member 3 in the reactor DB of the second embodiment, descriptions thereof are skipped.

[0110] The coil 1D is formed by coiling a plurality of band-shaped conductor members 13 such that the width direction of the conductor members 13 follows the axial direction of the coil 1D and such that conductor members 13 form layers stacked in the radial direction with insulating layers being disposed therebetween.

[0111] Since each of the reactors DE, DF, and DG of the fifth to seventh embodiments includes a plurality of sub-coils, it can be diverted to a transformer by changing connections of the sub-coils so that at least one of the sub-coils serves as a primary coil and at least one of the other sub-coils serves as a secondary coil. Such a transformer diverted from any of the reactors DE, DF, and DG of the fifth to seventh embodiments can have comparatively high mutual inductance with low levels of loss and noise.

[0112] For example, such a transformer diverted from any of the reactors DE, DF, and DG of the fifth to seventh embodiments can be used as a so-called insulation transformer, as shown by an equivalent circuit illustrated in Fig. 20(A), or can be used as a so-called choke transformer (filter), as shown by equivalent circuits illustrated in Figs. 20(B) and 20(C). Fig. 20(B) illustrates a common mode, and Fig. 20(C) illustrates a differential mode.

[0113] In the above-described embodiments, preferably, the thickness t of the conductor member in the coils 1A to 1D is less than or equal to the skin depth with respect to the frequency of alternating-current power to be fed to the reactors DA to DG. The reactors DA to DG thus structured can further reduce eddy current loss. In general, current flowing through the coil flows only in a region corresponding to the skin depth δ, but does not uniformly flow in the entire section of the conductor. Therefore, eddy current loss can be reduced by setting the thickness t of the conductor member to be less than or equal to the skin depth δ. When ω represents the angular frequency of the alternating-current power, μ represents the magnetic permeability of the conductor member, and p represents the electrical conductivity of the conductor member, the skin depth δ is generally equal to $(2/\omega\mu\rho)^{1/2}$.

[0114] While the core members 2A to 2D have magnetic isotropy and are formed of soft magnetic powder in the reactors DA to DG of the above-described embodiments, the core members 2A to 2D may be ferrite cores having magnetic isotropy. Such ferrite cores can comparatively easily realize a desired magnetic characteristic, and can be comparatively easily molded in a desired shape.

[0115] This description discloses a variety of aspects of techniques above. The following describes a summary of the main techniques.

[0116] A reactor according to an aspect includes a coil, a first core section encasing the coil, and a second core section provided in a core portion of the coil. The coil is formed by coiling a band-shaped conductor member such that a width direction of the conductor member follows an axial direction of the coil. One interior surface of the first core section, which faces one end part of the coil in the axial direction, and the other interior surface of the first core section, which faces the other end part of the coil in the axial direction, are parallel in a region that at least covers the one end part and the other end part of the coil. One end part of the second core section is positioned within an aperture part provided in the first core section, with a gap left between a circumference face of the one end part and a circumference face of the aperture part.

[0117] In the reactor thus structured, the coil is formed by coiling the band-shaped conductor member such that the width direction of the conductor member follows the axial direction of the coil, and one interior surface of the first core section, which faces one end part of the coil in the axial direction, and the other interior surface of the first core section, which faces the other end part of the coil in the axial direction, are parallel in the region that at least covers the one end part and the other end part of the coil. For this reason, since the width direction of the band-shaped conductor member follows the direction of magnetic flux in the coil, the reactor thus structured can reduce eddy current loss.

[0118] The reactor thus structured is a so-called pot type reactor including the first core section that encases the coil, and the coil has the second core section in its core portion. Hence, the reactor can have comparatively high inductance.

[0119] In the reactor thus structured, the one end part of the second core section is positioned in the aperture part of the first core section with the gap left between the interior surface of the one end part and the interior surface of the aperture part. Hence, the change in inductance within a desired current range can be controlled by adjusting the distance of the gap (gap length). For example, since the gap length is defined by the difference between the diameter (inner diameter) of the aperture part of the first core section and the diameter (outer diameter) of the one end part of the second core section when the aperture part is circular and the one end part is also circular, the reactor thus structured can suppress the change in the gap length due to misalignment between the center of the aperture part and the center of the one end part. For this reason, in the reactor thus structured, product-to-product variations in the gap length (differences among individual reactors) are reduced. As a result, the reactor thus structured can also reduce product-to-product variations in inductance.

[0120] While both electromagnetic attractive force and magnetostrictive expansion are typically produced in the radial direction in the gap, the reactor thus structured can reduce vibration and noise because it has high mechanical rigidity in the radial direction. As measures against noise, even when the reactor is operated at high frequency, for example, so that noise is above an audible band of about 18 kHz or more, since the eddy current loss is reduced, as described above, loss can also be reduced.

[0121] Therefore, the reactor thus structured can provide comparatively high inductance with low levels of loss and noise.

[0122] According to another aspect, in the above-described reactor, the other end part of the second core section is coupled to the first core section, and the first core section further includes a projection extending from a peripheral edge portion that forms the aperture part into the first core.

[0123] When high inductance is designed by increasing the number of turns of the coil, lines of magnetic flux passing through the coil during energization are curved in the reactor that does not include the projection. In contrast, since the direction of lines of magnetic flux passing through the coil during energization can be made close to the direction parallel to the axial direction in the reactor thus structured. Hence, the reactor thus structured can achieve less eddy current loss than when the reactor does not include the projection.

[0124] According to a further aspect, in the above-described reactor, the other end part of the second core section is positioned in a second aperture part provided in the first core section, with a second gap left between a circumference face of the other end part and a circumference face of the second aperture part.

[0125] Since the reactor thus structured includes a plurality of gaps, that is, the gap (first gap) and the second gap, the gaps can be arranged separately. For this reason, the reactor thus structured can reduce magnetic flux leaking outside, and as a result, can minimize the influence of leakage flux on peripheral devices arranged around the reactor.

[0126] According to a further aspect, the above-described reactor further includes a mount member on which the reactor is to be mounted. The mount member is formed of a material having electrical conductivity and thermal conductivity, and has, on a mount surface on which the reactor is to be mounted, a slit hole whose longitudinal direction intersects the second gap in plan view, as viewed in the axial direction of the coil and that penetrates through the mount member, or a slit groove whose longitudinal direction intersects the second gap in plan view and that has a depth larger than or equal to a distance of the second gap.

[0127] In the reactor having such a structure, since the mount member has thermal conductivity, it can radiate heat produced in the reactor. When the reactor has the second gap, since the mount member has electrical conductivity, leakage flux leaking out due to the second gap may cause eddy current in the mount member. However, in the reactor having the above structure, the flow of the eddy current is prevented because the mount member has the slit hole or the slit groove. Therefore, such a reactor can radiate heat without causing any power loss and any inductance change.

[0128] According to a further aspect, in the above-described reactor, the other end part of the second core section is provided with a third gap from the other interior surface of the first core section.

[0129] Since the reactor thus structured includes a plurality of gaps, that is, the gap (first gap) and the third gap, the gaps can be arranged separately. For this reason, the reactor thus structured can reduce magnetic flux leaking outside, and as a result, can minimize the influence of leakage flux on peripheral devices arranged around the reactor.

[0130] According to a further aspect, in the above-described reactor, a ratio t/W of a thickness t in a radial direction to a width W of the conductor member of the coil is 1/10 or less.

[0131] The reactor thus structured can further reduce eddy current loss.

[0132] According to a further aspect, in the above-described reactors, the thickness t of the conductor member of the coil is smaller than or equal to a skin depth with respect to a frequency of alternating-current power to be fed to the reactors.

[0133] The reactor thus structured can further reduce eddy current loss.

[0134] According to a further aspect, in the above-described reactors, the first core section has magnetic isotropy, and is formed of soft magnetic powder.

[0135] According to this structure, the first core section can comparatively easily obtain a desired magnetic characteristic, and can be comparatively easily molded in a desired shape.

[0136] According to a further aspect, in the above-described reactors, the first core section is formed by a ferrite core having magnetic isotropy.

[0137] According to this structure, the first core section can comparatively easily obtain a desired magnetic characteristic, and can be comparatively easily molded in a desired shape.

[0138] According to a further aspect, the above-described reactors each further includes a heat transfer material to be filled in a gap provided between the coil and the first core section.

[0139] According to this structure, since the gap is filled with the heat transfer material, in the reactor thus structured, heat produced in the coil can be transferred via the heat transfer material to the first core section surrounding the coil. This can improve heat radiation performance.

[0140] According to a still further aspect, in the above-described reactors, the coil is formed by a plurality of sub-coils and is divertible to a transformer.

[0141] According to this structure, it is possible to provide a transformer having a structure similar to the structures of the above-described reactors. The transformer diverted from any of the above-described reactors can provide comparatively high mutual inductance with low levels of loss and noise.

[0142] According to a still further mode, in the above-described reactors, the coil is formed by a plurality of sub-coils, and the sub-coils are stacked in the axial direction of the coil.

[0143] According to this structure, it is possible to provide a reactor in which a plurality of sub-coils are stacked in the axial direction.

[0144] According to a still further aspect, in the above-described reactors, the coil is formed by a plurality of sub-coils, and the sub-coils are stacked in a radial direction of the coil.

[0145] According to this structure, it is possible to provide a reactor in which a plurality of sub-coils are stacked in the radial direction.

[0146] According to a still further aspect, in the above-described reactors, the coil is formed by coiling a plurality of band-shaped conductor members such that a width direction of the conductor members follows the axial direction of the coil and such that the conductor members form layers stacked in a radial direction with insulating layers being disposed therebetween.

[0147] According to the structure in which a plurality of sub-coils are provided, it is possible to provide a transformer having a structure similar to the structures of the above reactors. Such a transformer diverted from any of the above-described reactors can provide comparatively high mutual inductance with low levels of loss and noise.

[0148] The present application is based on Japanese Patent Application No. 2010-163863 filed July 21, 2010 and No. 2011-130858 filed June 13, 2011, and the contents of which are incorporated herein by reference.

[0149] While the present invention has been properly and fully described above by way of the embodiments with reference to the drawings, it is to be recognized that a person skilled in the art could have easily change and/or improve the above embodiments. Therefore, as long as the changes or improvements made by the person skilled in the art do not depart from the scope of the claims, such changes or the improvements should be construed as being included in the scope of the claims.

Industrial Applicability

[0150] According to the present invention, a reactor can be provided.

Claims

1. A reactor comprising:

> a coil;
> a first core section encasing the coil; and
> a second core section provided in a core portion of the coil,
> wherein the coil is formed by coiling a band-shaped conductor member such that a width direction of the conductor member follows an axial direction of the coil,
> wherein one interior surface of the first core section, which faces one end part of the coil in the axial direction, and the other interior surface of the first core section, which faces the other end part of the coil in the axial direction, are parallel in a region that at least covers the one end part and the other end part of the coil, and
> wherein one end part of the second core section is positioned within an aperture part, which is formed in the first core section, with a gap left between a circumference face of the one end part and a circumference face of the aperture part.

2. The reactor according to Claim 1,
wherein the other end part of the second core section is coupled to the first core section, and
wherein the first core section further includes a projection extending from a peripheral edge portion that forms the aperture part into the first core section.

3. The reactor according to Claim 1, wherein the other end part of the second core section is positioned in a second aperture part provided in the first core section, with a second gap left between a circumference face of the other end part and a circumference face of the second aperture part.

4. The reactor according to Claim 3, further comprising:

a mount member on which the reactor is mounted,
wherein the mount member is formed of a material having electrical conductivity and thermal conductivity, and has, on a mount surface on which the reactor is mounted, a slit hole whose longitudinal direction intersects the second gap in plan view, as viewed in the axial direction of the coil and that penetrates through the mount member, or a slit groove whose longitudinal direction intersects the second gap in plan view and that has a depth larger than or equal to a distance of the second gap.

5. The reactor according to Claim 1, wherein the other end part of the second core section is provided with a third gap from the other interior surface of the first core section.

6. The reactor according to any one of Claims 1 to 5, wherein a ratio t/W of a thickness t in a radial direction to a width W of the conductor member of the coil is 1/10 or less.

7. The reactor according to any one of Claims 1 to 5, wherein the thickness t of the conductor member of the coil is less than or equal to a skin depth relative to a frequency of alternating-current power to be fed to the reactor.

8. The reactor according to any one of Claims 1 to 5, wherein the first core section has magnetic isotropy, and is formed of soft magnetic powder.

9. The reactor according to any one of Claims 1 to 5, wherein the first core section is formed by a ferrite core having magnetic isotropy.

10. The reactor according to any one of Claims 1 to 5, further comprising:

a heat transfer material to be filled in a gap provided between the coil and the first core section.

11. The reactor according to any one of Claims 1 to 5, wherein the coil is formed by a plurality of sub-coils and is divertible to a transformer.

12. The reactor according to any one of Claims 1 to 5, wherein the coil is formed by a plurality of sub-coils, and
wherein the sub-coils are stacked in the axial direction of the coil.

13. The reactor according to any one of Claims 1 to 5, wherein the coil is formed by a plurality of sub-coils, and
wherein the sub-coils are stacked in a radial direction of the coil.

14. The reactor according to any one of Claims 1 to 5, wherein the coil is formed by coiling a plurality of band-shaped conductor members such that a width direction of the conductor members follows the axial direction of the coil and such that the conductor members form layers stacked in a radial direction with insulating layers being disposed therebetween.

FIG. 1

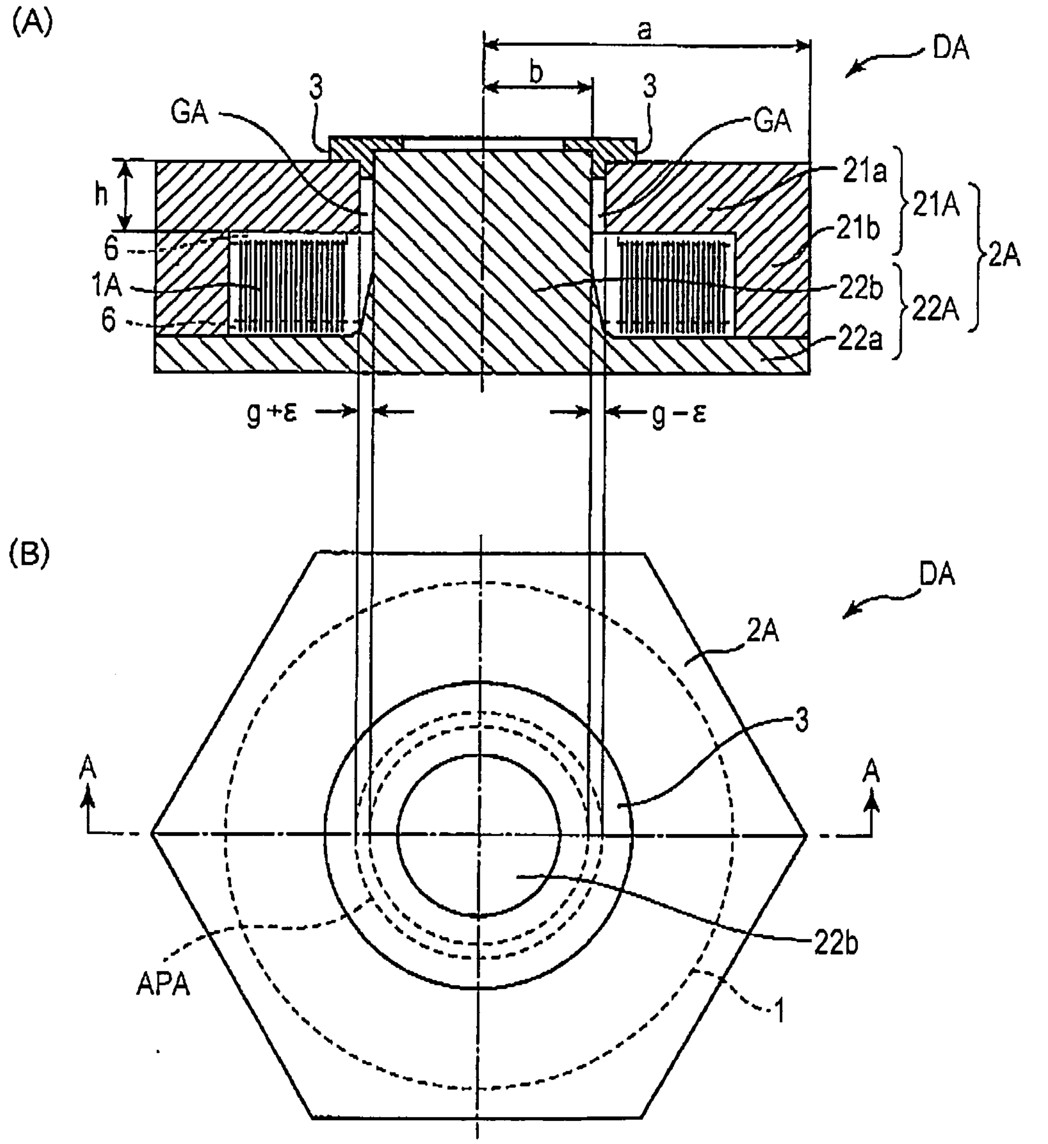

(A)
a
b
DA
3
3
GA
GA
h
21a
21A
21b
2A
6
1A
22b
22A
6
22a
g+ε
g−ε
(B)
DA
2A
3
A
A
22b
APA
1

FIG. 2

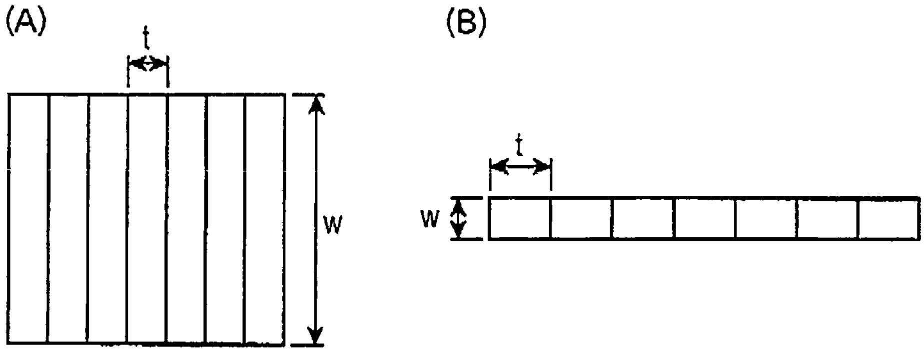


FIG. 3

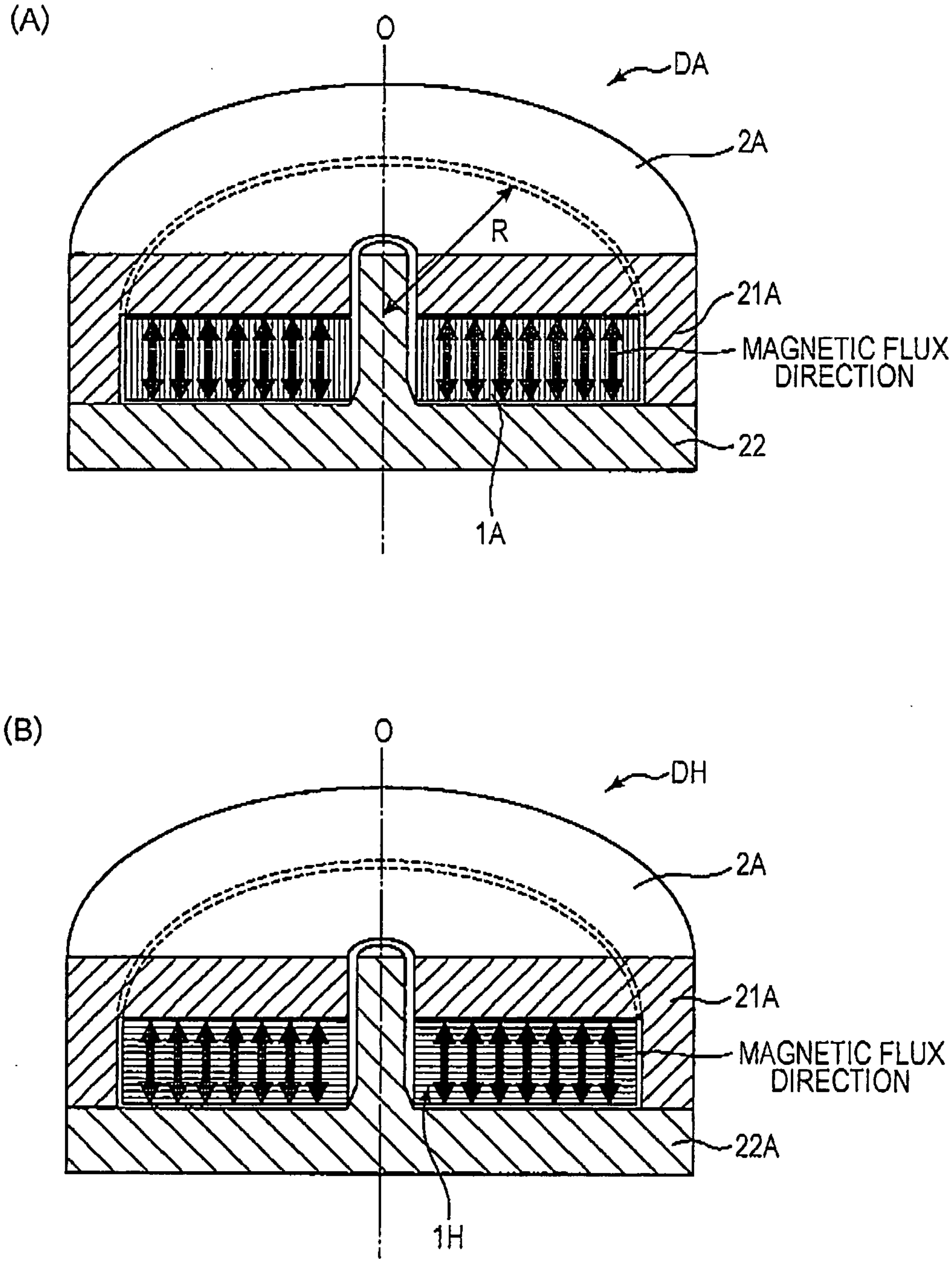

(A)
O
DA
2A
R
21A
MAGNETIC FLUX DIRECTION
22
1A
(B)
O
DH
2A
21A
MAGNETIC FLUX DIRECTION
22A
1H

FIG. 4

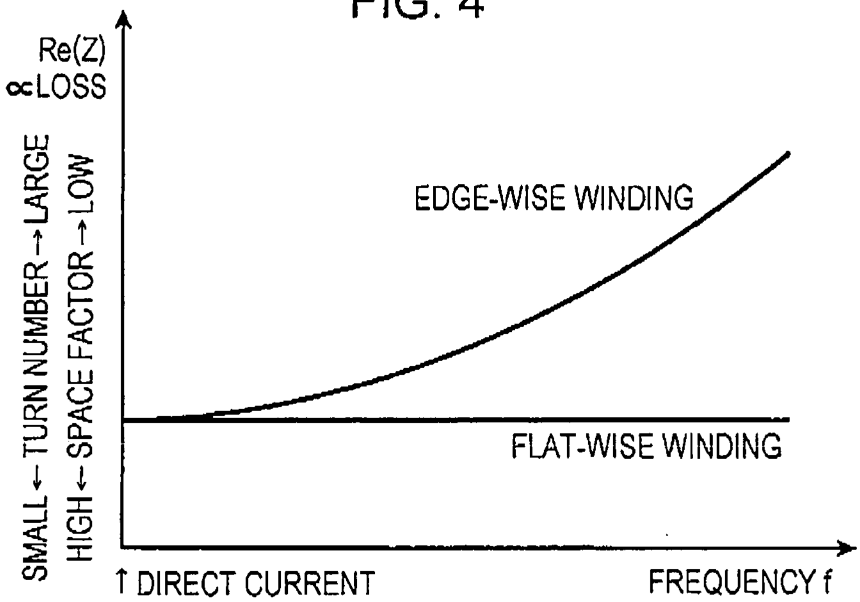

Re(Z)
∝LOSS
SMALL ← TURN NUMBER → LARGE
HIGH ← SPACE FACTOR → LOW
EDGE-WISE WINDING
FLAT-WISE WINDING
↑ DIRECT CURRENT
FREQUENCY f

FIG. 5

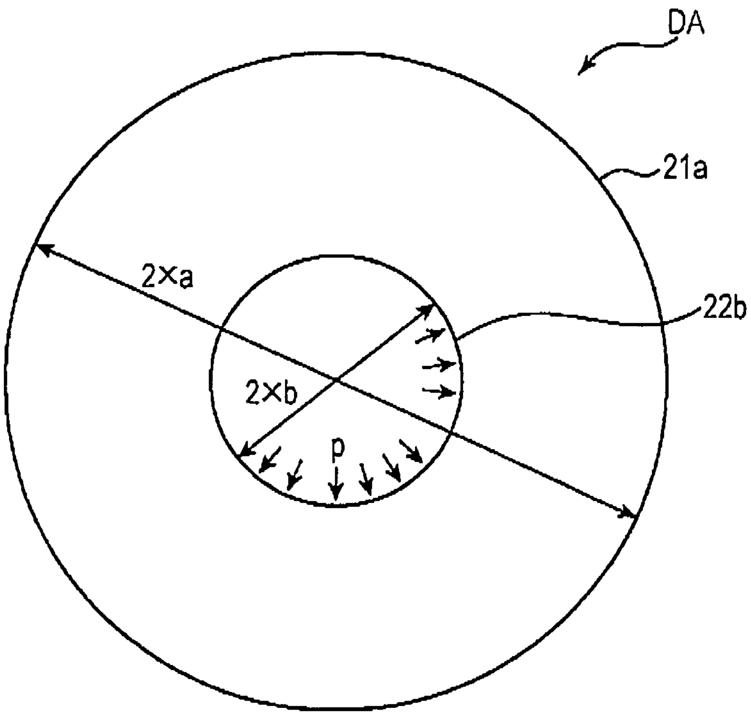

DA
21a
2×a
22b
2×b
p

FIG. 6

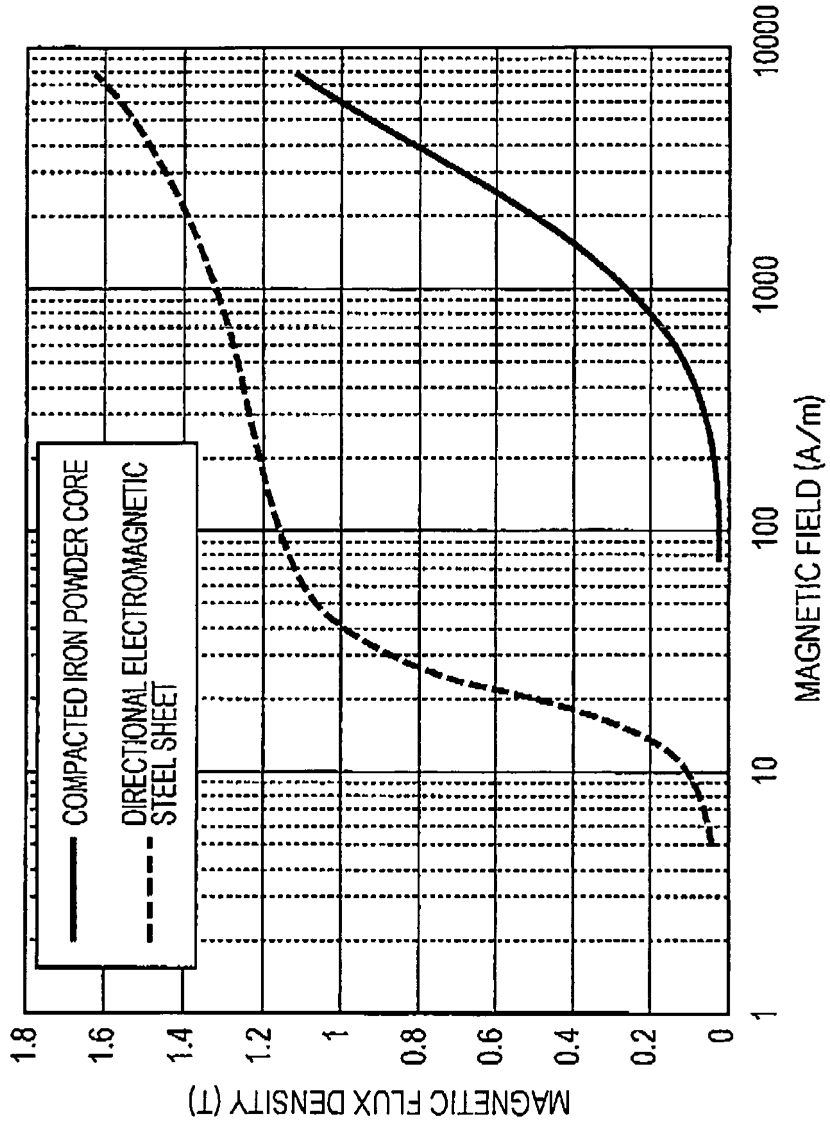

COMPACTED IRON POWDER CORE
DIRECTIONAL ELECTROMAGNETIC STEEL SHEET
MAGNETIC FLUX DENSITY (T)
MAGNETIC FIELD (A/m)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
10
100
1000
10000

FIG. 7

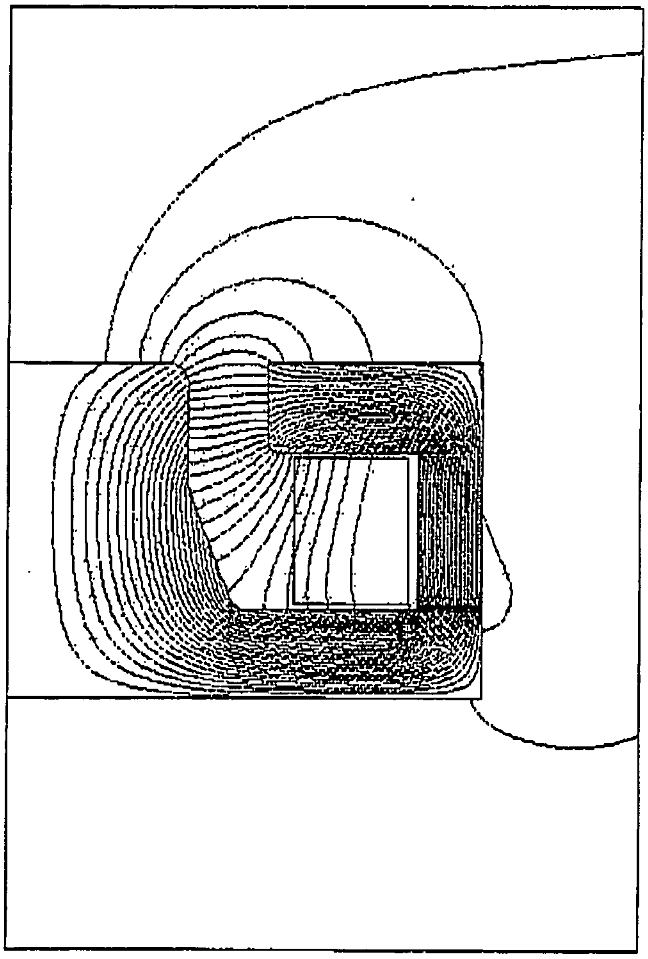


FIG. 8

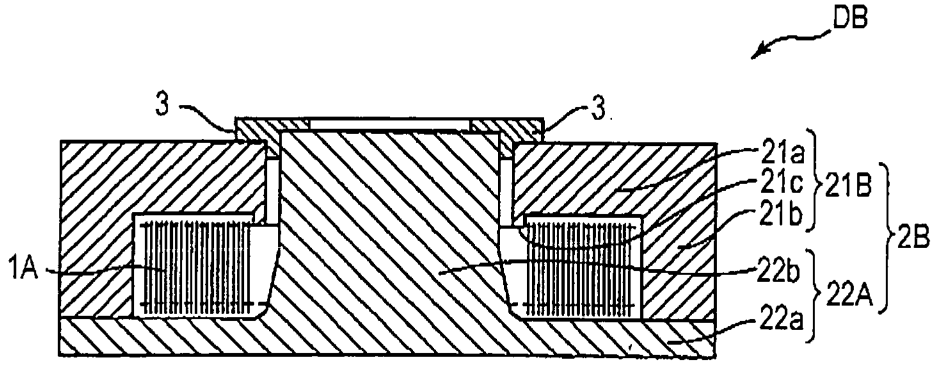


FIG. 9

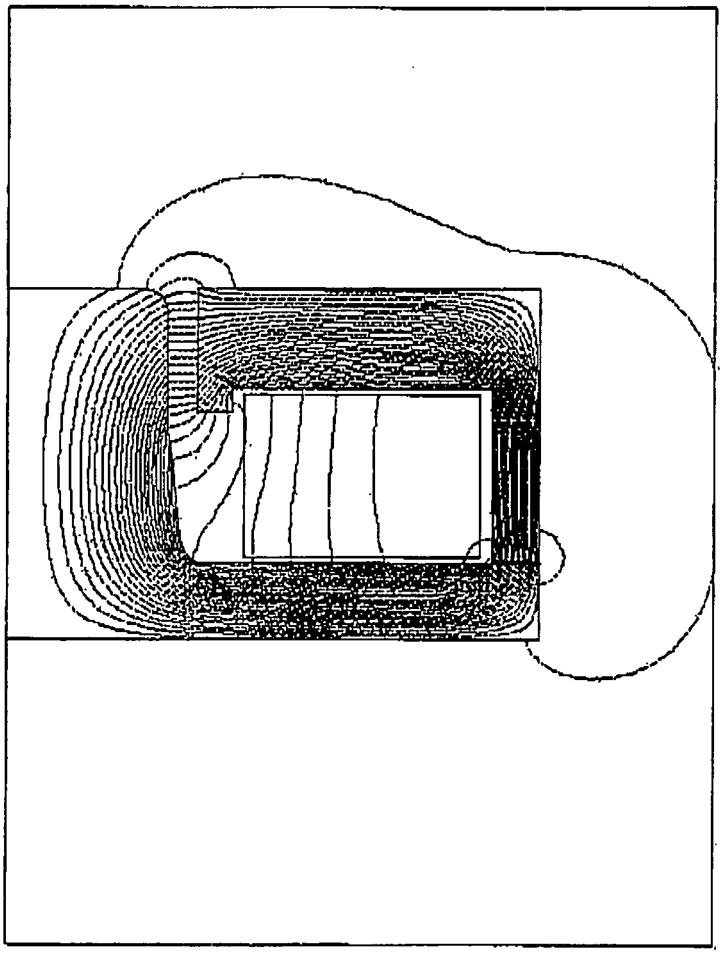


FIG. 10

(B)

(A)

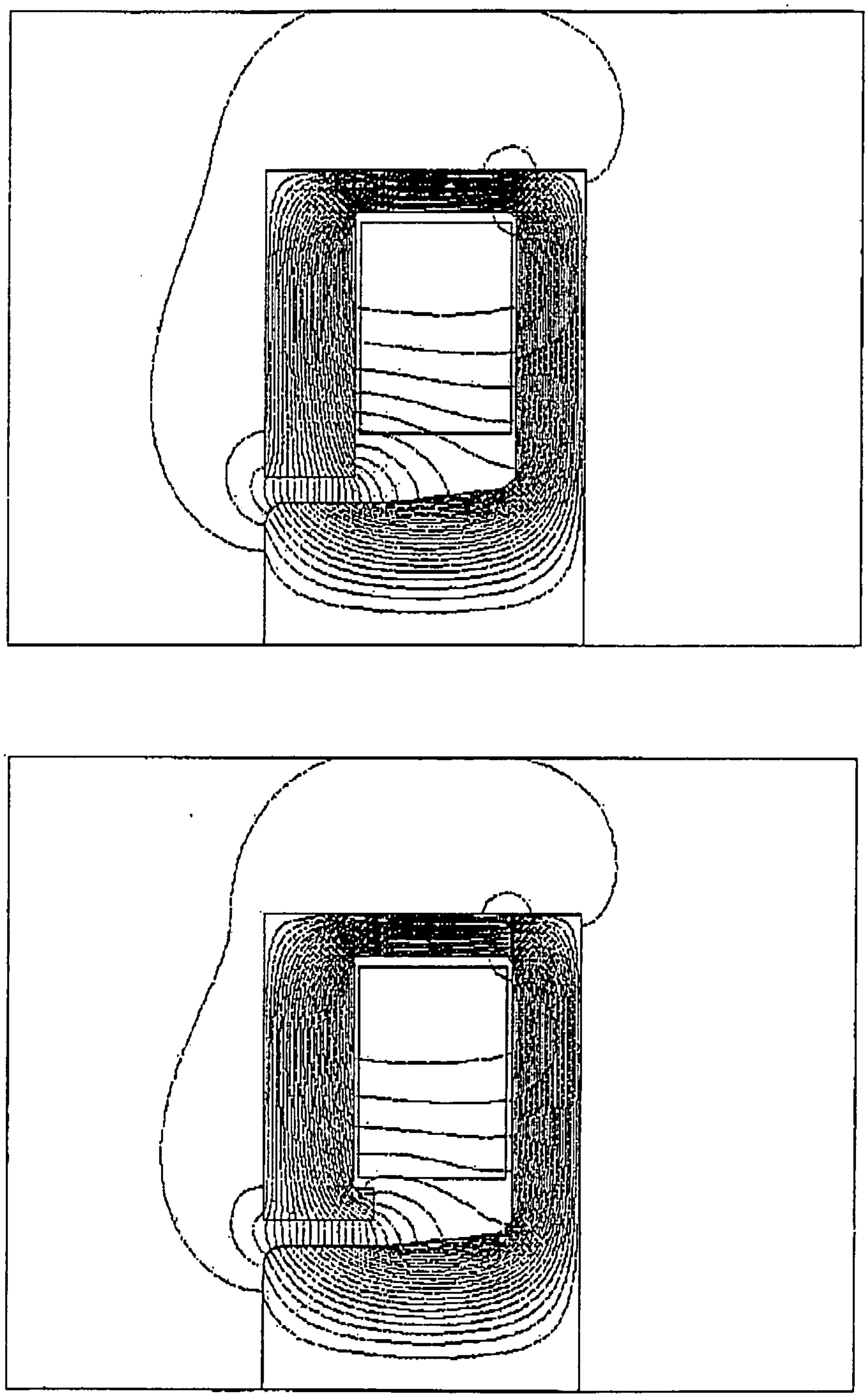


FIG. 11

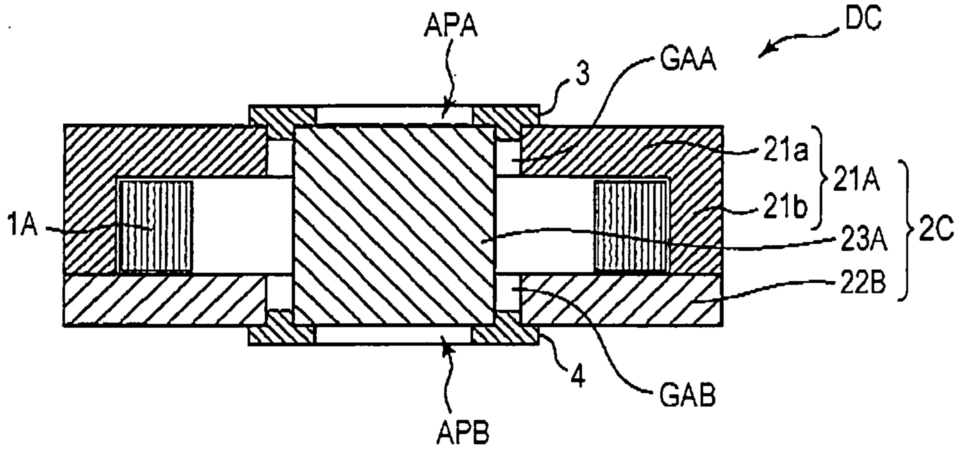


FIG. 12

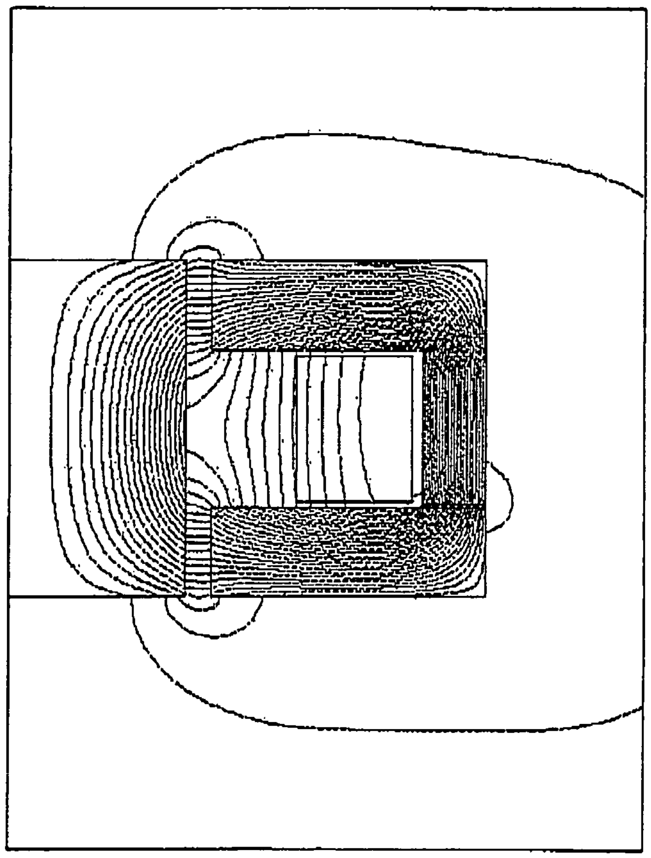
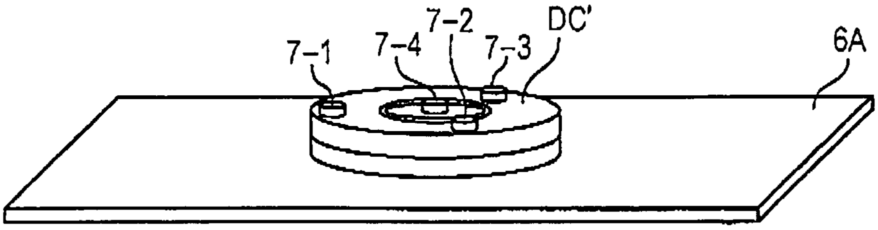
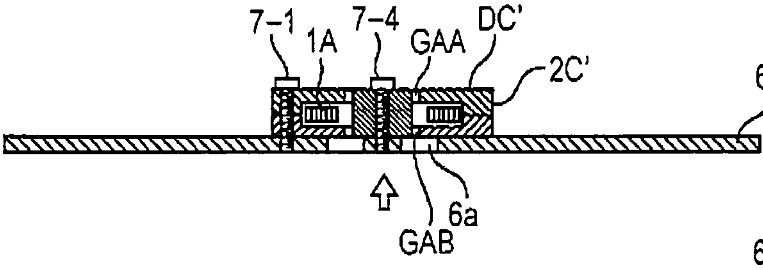


FIG. 13

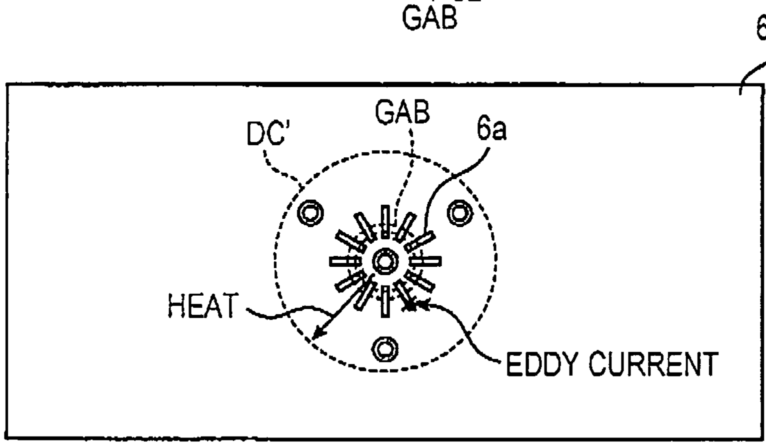
(A)


7-1
7-4
7-2
7-3
DC'
6A

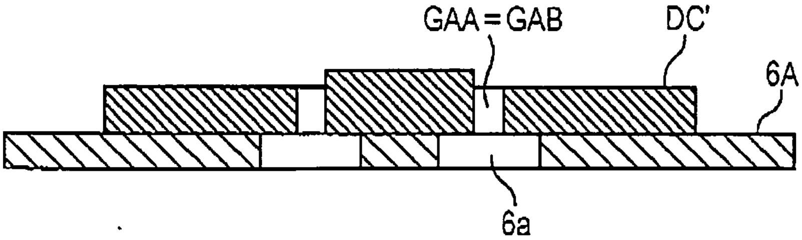
(B)


7-1
1A
7-4
GAA
DC'
2C'
6A
6a
GAB

(C)


6A
GAB
DC'
6a
HEAT
EDDY CURRENT

(D)


GAA=GAB
DC'
6A
6a

(E)

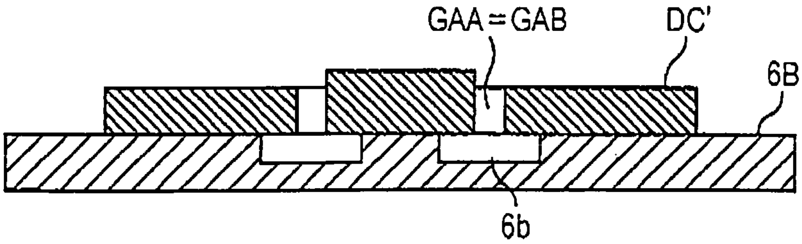

GAA≈GAB
DC'
6B
6b

FIG. 14

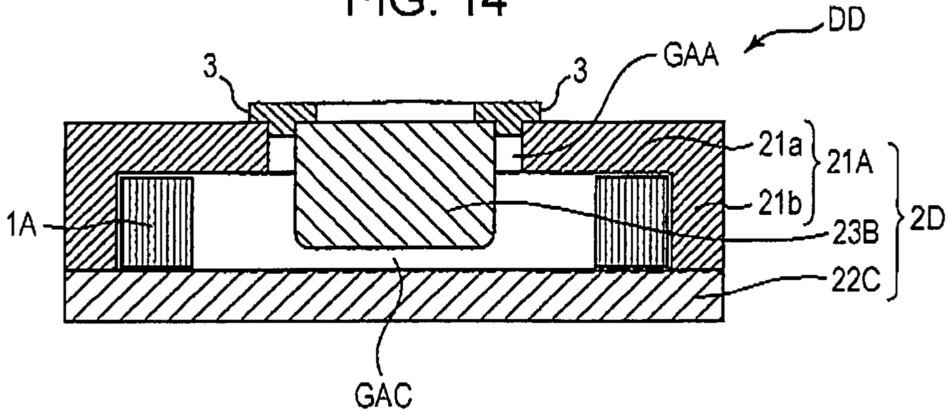


FIG. 15

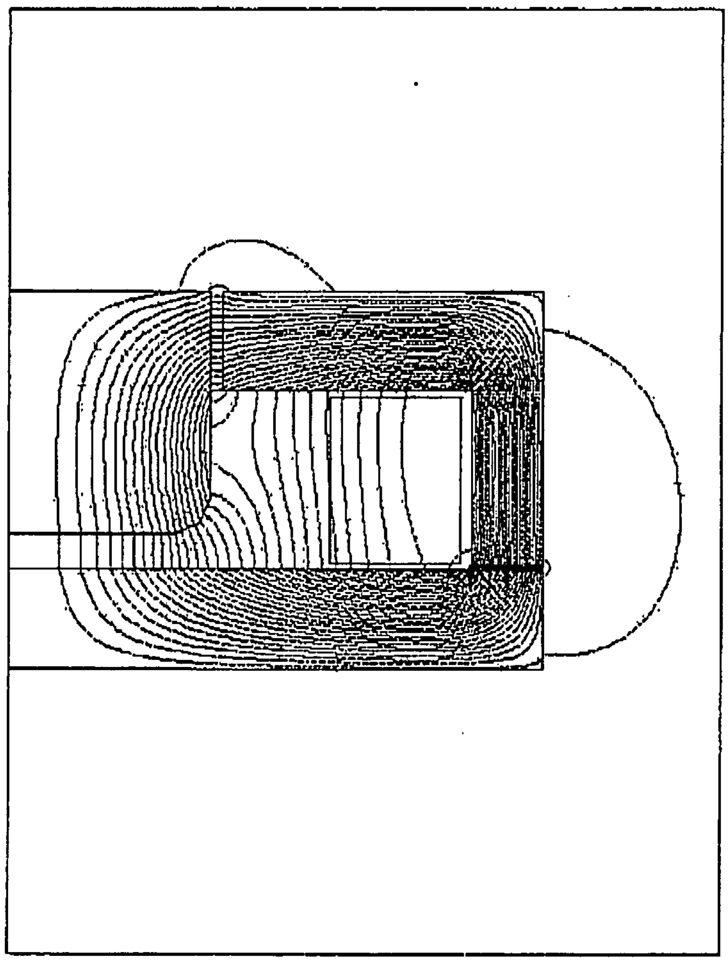


FIG. 16

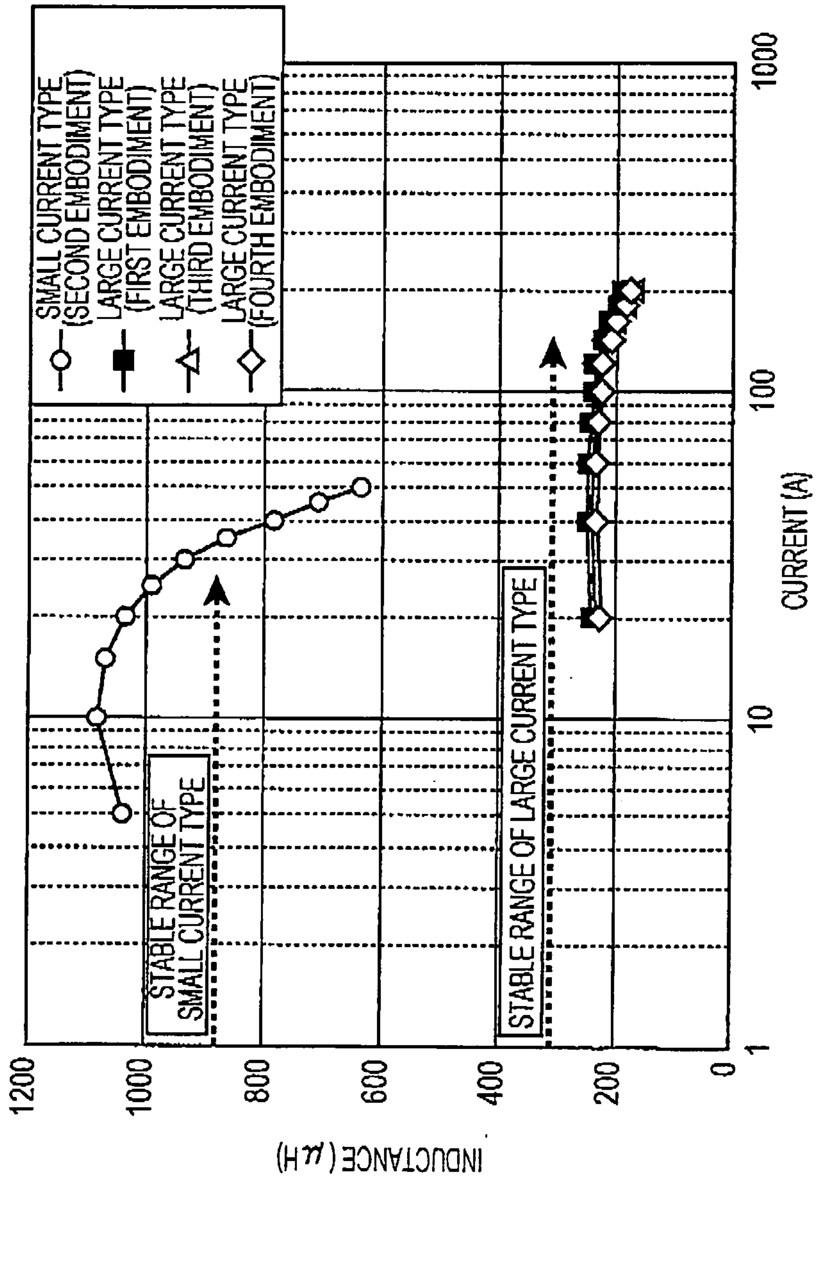

SMALL CURRENT TYPE (SECOND EMBODIMENT)
LARGE CURRENT TYPE (FIRST EMBODIMENT)
LARGE CURRENT TYPE (THIRD EMBODIMENT)
LARGE CURRENT TYPE (FOURTH EMBODIMENT)
STABLE RANGE OF SMALL CURRENT TYPE
STABLE RANGE OF LARGE CURRENT TYPE
INDUCTANCE (μH)
1200
1000
800
600
400
200
0
CURRENT (A)
1
10
100
1000

FIG. 17

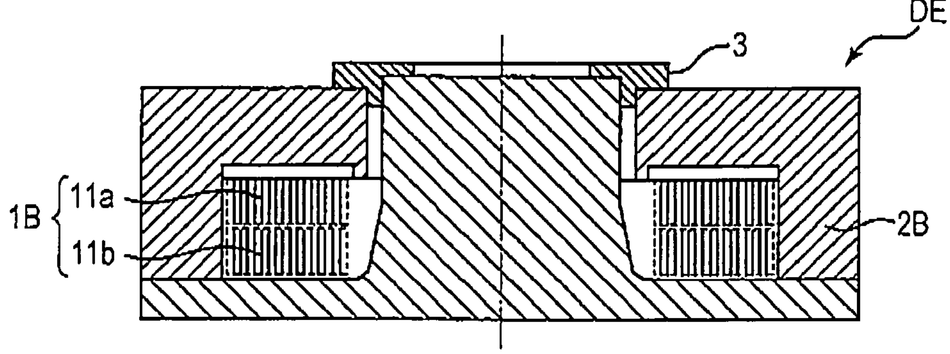


FIG. 18

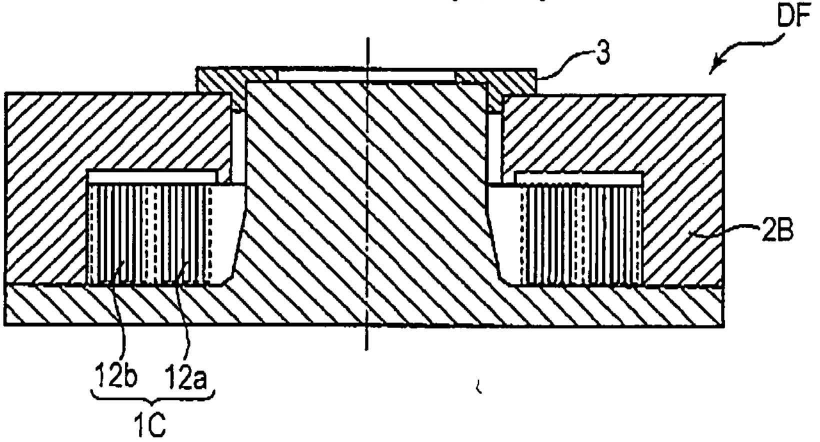


FIG. 19

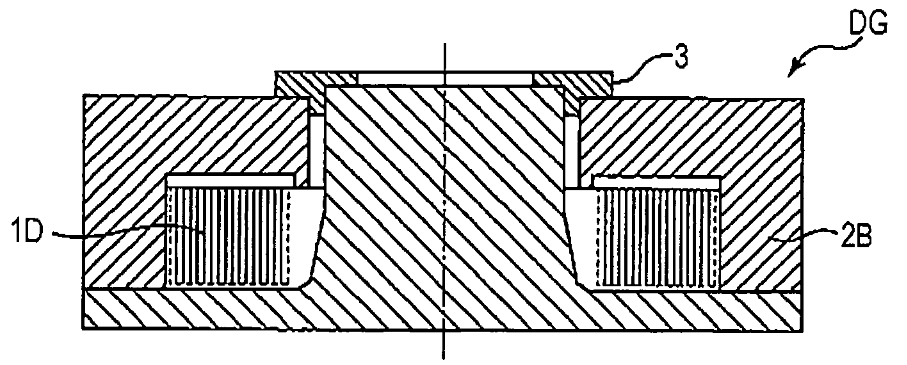


FIG. 20

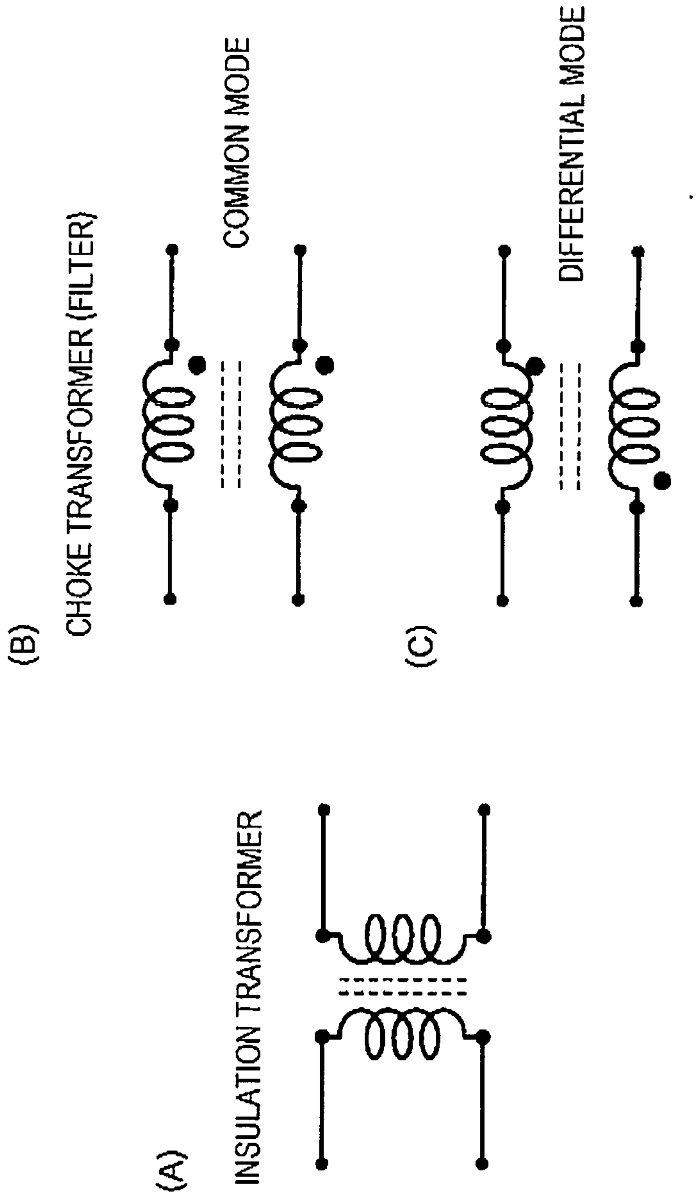
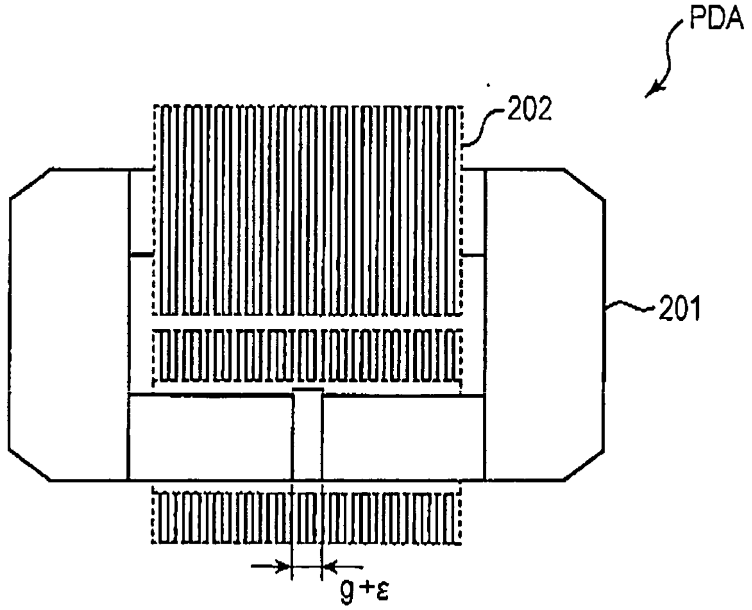

(A)
INSULATION TRANSFORMER
(B)
CHOKE TRANSFORMER (FILTER)
COMMON MODE
(C)
DIFFERENTIAL MODE

FIG. 21

(A)



(B)

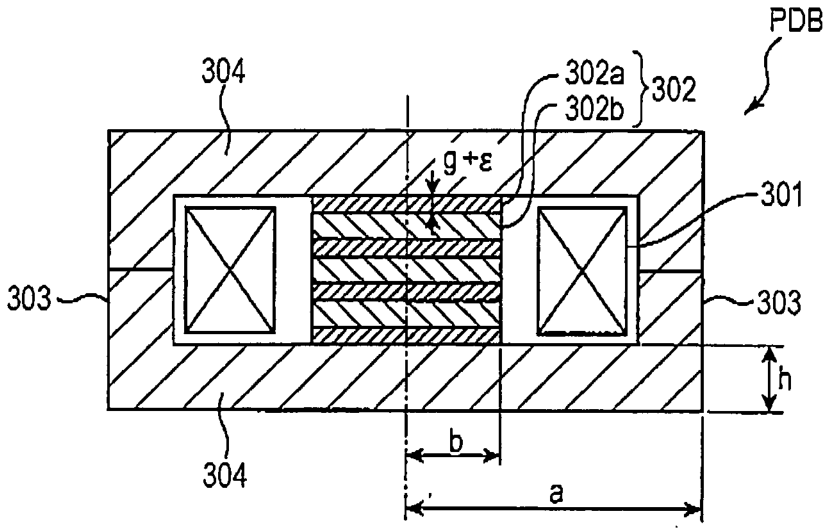
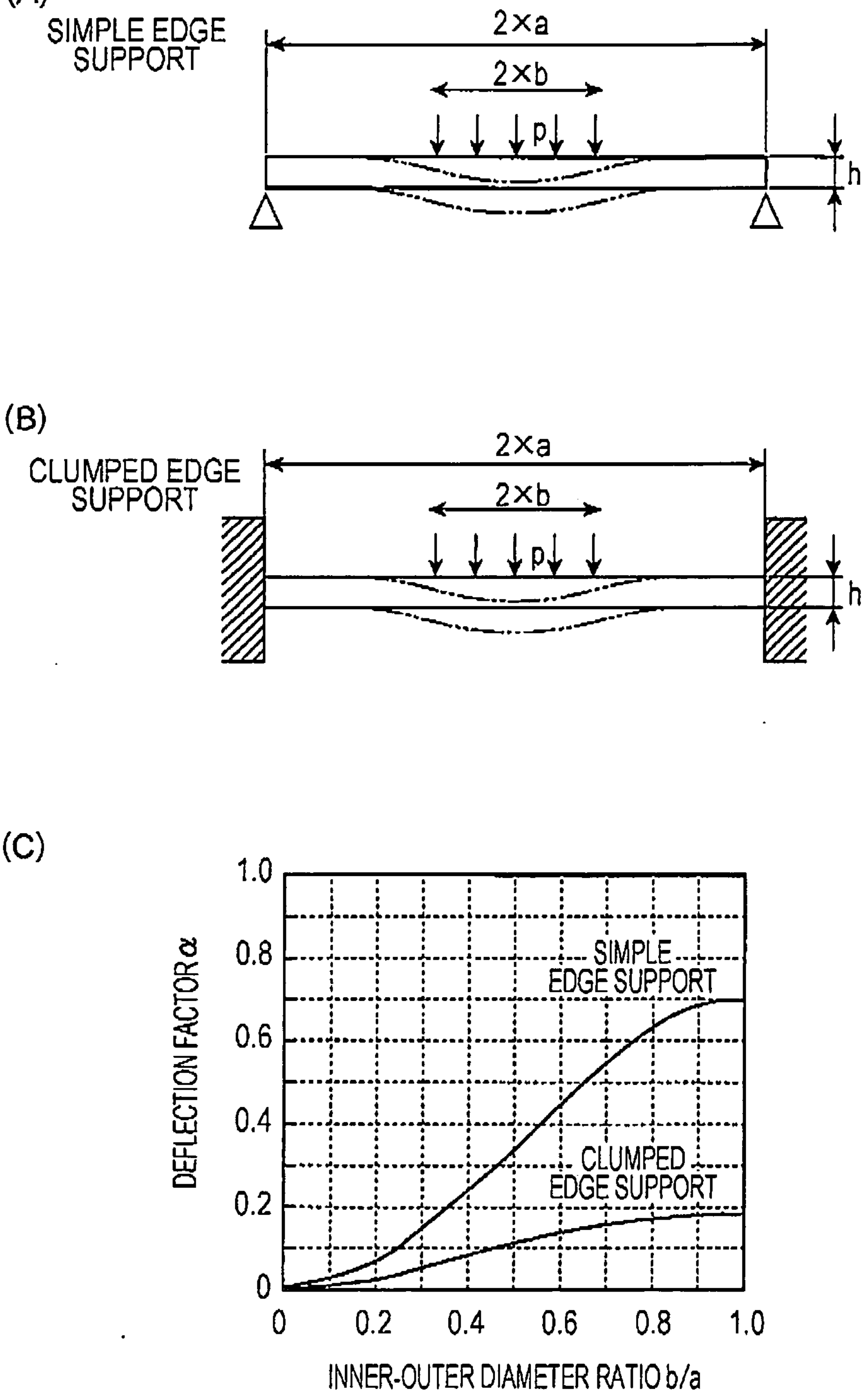


FIG. 22

(A)


SIMPLE EDGE SUPPORT
2×a
2×b
p
h
(B)
CLUMPED EDGE SUPPORT
2×a
2×b
p
h
(C)
1.0
0.8
0.6
0.4
0.2
0
DEFLECTION FACTOR α
SIMPLE EDGE SUPPORT
CLUMPED EDGE SUPPORT
0
0.2
0.4
0.6
0.8
1.0
INNER-OUTER DIAMETER RATIO b/a

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2011/004097

A. CLASSIFICATION OF SUBJECT MATTER
H01F37/00(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)
H01F37/00, H01F27/24-27/30

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

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.
Y A	JP 2001-167939 A (Tokyo Coil Engineering Co., Ltd.), 22 June 2001 (22.06.2001), paragraphs [0013] to [0022]; fig. 1 to 2 & TW 434593 B	1,3-14 2
Y	JP 2000-40626 A (Matsushita Electric Industrial Co., Ltd.), 08 February 2000 (08.02.2000), paragraphs [0143] to [0145], [0152] to [0158]; fig. 86 to 88, 95 to 97 (Family: none)	1,3-14

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

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Date of the actual completion of the international search	Date of mailing of the international search report
17 October, 2011 (17.10.11)	25 October, 2011 (25.10.11)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2011/004097

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CD-ROM of the specification and drawings annexed to the request of Japanese Utility Model Application No. 67555/1992(Laid-open No. 26222/1994) (Minebea Co., Ltd.), 08 April 1994 (08.04.1994), entire text; all drawings (Family: none)	1,3-14
Y	JP 3-208317 A (Matsushita Electric Industrial Co., Ltd.), 11 September 1991 (11.09.1991), page 2, upper left column, line 18 to upper right column, line 14; fig. 4 (Family: none)	3-4,6-14
Y	JP 11-345724 A (Matsushita Electric Industrial Co., Ltd.), 14 December 1999 (14.12.1999), paragraphs [0034] to [0039]; fig. 8 to 9 (Family: none)	4,6-14
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 9130/1983(Laid-open No. 117120/1984) (Toyo Electric Mfg. Co., Ltd.), 07 August 1984 (07.08.1984), specification, page 3, lines 1 to 6; page 6, line 2 to page 7, line 17; fig. 3 to 5 (Family: none)	4,6-14
Y	JP 2006-32560 A (TDK Corp.), 02 February 2006 (02.02.2006), paragraphs [0009] to [0017]; fig. 3 (Family: none)	5-14
Y	JP 2006-310550 A (Tamura Corp.), 09 November 2006 (09.11.2006), paragraphs [0011], [0019] to [0020]; fig. 2 (Family: none)	10

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REFERENCES CITED IN THE DESCRIPTION

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