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(54) **Coil component, method of manufacturing coil component, and coil component set**

(57) A coil component (100) of the present invention has an annular coil core (110) composed of a material having a higher permeability than that of air, and a winding (120) wound around the coil core (110) in close prox-

imity thereto; and a cross section of the coil core (110), which is taken orthogonally to the winding axis of the winding (120), deviates either towards the inner loop side or towards the outer loop side of the coil core (110).

Fig. 2A

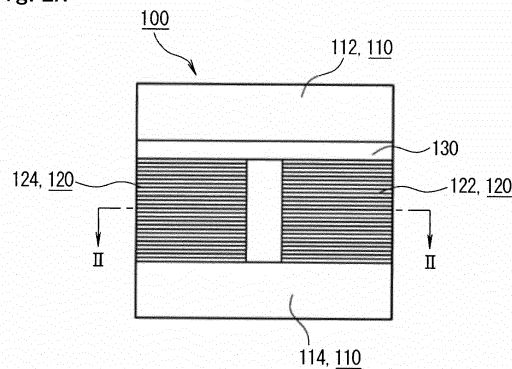
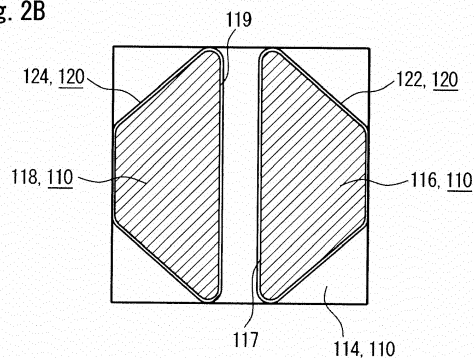


Fig. 2B



Description

[0001] This application is based on Japanese patent application No. 2013-262538, filed on December 19, 2013, the content of which is incorporated hereinto by reference.

BACKGROUND**TECHNICAL FIELD**

[0002] The present invention relates to a coil component, a method of manufacturing the coil component, and a coil component set.

RELATED ART

[0003] In this specification, coil component refers to a coil having a conducting wire wound in an annular or spiral manner, or a component (element) containing such coil, which is a passive element capable of storing energy in a magnetic field induced by electric current which flows therethrough. The coil component has variable names depending on its purpose of use, shape, material, structure and so forth. For example, the coil component used mainly in the field of power electronics is referred to as reactor, and the coil component used mainly in control circuits is referred to as inductor. The coil component directed to block (attenuate) current at a frequency higher than that of a desired current is referred to as choke coil. For the case where a plurality of coils, which are electrically isolated and magnetically coupled, are configured so that one of them stores energy in a magnetic field induced by electric current which flows therethrough, and the other of them outputs the energy after converting it into electric current, a coil component including such plurality of coils is referred to as transformer.

[0004] Patent Document 1 is now exemplified as this sort of technology. Patent Document 1 describes a coil component (reactor) in which a coil core is configured, by combining a member composed of a pair of flat plate-like magnetic materials, and a pair of columnar magnetic materials, to form a closed magnetic path structure of a magnetic material. Patent Document 1 describes that variation in resistivity value of the coil component may be reduced, by properly adjusting a ratio between the total thickness of gaps formed between the flat plate-like members and the columnar components, and the thickness of gaps provided in the middle way of the columnar components.

[0005] Exemplified now are Patent Document 2 and Patent Document 3 which disclose, as techniques relevant to that described above, specially-shaped coil cores aimed at adjusting magnetic characteristics of the coil components.

[0006] Patent Document 2 describes a coil component characterized by a special shape of its so-called toroidal core. The toroidal core is formed so as to gradually increase or decrease the diameter of winding wound around the outer circumference, along the circumferential direction. With this configuration, use of only a single coil component is enough to achieve a high attenuation characteristic over a wide frequency range.

[0007] Patent Document 3 describes a coil component having an annular coil core which is divided into eight constituents arranged while placing a gap between every adjacent constituents. The cross-sectional area of the constituents having no winding wound therearound is smaller than the cross-sectional area of the other constituents having the winding wound therearound. With this configuration, the coil component is successfully reduced in size, and also successfully improved in DC superimposition characteristic of the coil component.

Patent Document 1: Japanese Patent Application Laid-Open No. 2009-259971

Patent Document 2: International Publication WO2008/084684 Patent Document 3: Japanese Patent Application Laid-Open No. 2007-243136

[0008] Although being configured to have a somewhat simple structure, the coil component has a variety of parameters which are mutually correlated in an intricate manner. It is therefore not easy to optimize them respectively. In particular, as for the coil component having a coil core (magnetic core) inserted therein, invisible electromagnetic action of the coil core heavily affects the characteristics and state of operation of the coil component. The engineers have therefore had no choice but to work out details by repeating trial and error, and have had to expend a great deal of labor to achieve a desired product specification.

[0009] The coil components described in the above individual Patent Documents are intended to improve the specific parameters by providing the coil cores with some structural features. All of such structural features however largely affect parameters other than the targeted parameters. The conventional coil components are therefore still suffering from the above-described problems, in that they cannot satisfy their desired product specifications without taking the influences on the other parameters into consideration.

SUMMARY

[0010] The present invention is conceived considering the above-described problems, and is to provide a coil component capable of readily achieving desired magnetic characteristics, a method of manufacturing such coil component, and a coil component set.

[0011] According to the present invention, there is provided a coil component which includes:

an annular coil core composed of a material having a higher permeability than that of air; and
a winding wound around the coil core in close proximity thereto,
a cross section of the coil core, which is taken orthogonally to the winding axis of winding, deviating either towards the inner loop side or towards the outer loop side of the coil core.

[0012] According to the present invention, there is provided a method of manufacturing a coil component having an annular coil core composed of a material having a higher permeability than that of air, and a winding wound around the coil core in close proximity thereto, the method includes:

deriving the degree of deviation of a cross section of the coil core, which is taken orthogonally to the winding axis of winding, either towards the inner loop side or towards the outer loop side of the coil core, based on a desired inductance of the coil component;

determining a shape of the coil core, according to the degree derived in the preceding step of derivation; and
molding the coil component, according to the shape of coil core determined in the preceding step of shape determination.

[0013] According to the present invention, there is provided a coil component set which includes a plurality of coil components each having an annular coil core composed of a material having a higher permeability than that of air, and a winding wound around the coil core in close proximity thereto, and,

among the plurality of coil components having equivalent levels of either one of inductance and DC superimposition characteristic,

a cross section of the coil core in a first coil component, which is taken orthogonally to the winding axis of winding, deviating either towards the inner loop side or towards the outer loop side of the coil core, more largely as compared with the cross section of the coil core in a second coil component.

[0014] The coil component of the present invention is configured so that the cross section of the annular coil core, which is taken orthogonally to the winding axis of winding, deviates either towards the inner loop side or towards the outer loop side of the coil core.

[0015] With this configuration, ratios of the area of coil core in the cross section thereof will be different between the side of deviation and the opposite side, resulting in a stronger magnetic field on the side of deviation. In other words, an effective magnetic path of the coil component as a whole deviates towards the side of deviation. Accordingly, the coil component of the present invention will have an effective magnetic path length (average magnetic path length) which substantially shortens or elongates, and the inductance will increase or decrease as a consequence, as compared with the coil component having equivalent DC superimposition characteristic but having a non-deviating cross section of the core.

[0016] In short, according to the method of manufacturing a coil component of the present invention, it now becomes possible to manufacture a coil component which satisfies a desired inductance almost without affecting the DC superimposition characteristic. Accordingly, a coil component with desired magnetic characteristics may readily be achieved.

[0017] According to the present invention, a coil component, a method of manufacturing a coil component and a coil component set, all being aimed at achieving a desired magnetic characteristics, are successfully provided in an easy manner.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The above and other objects, advantages and features of the present invention will be more apparent from the following description of certain preferred embodiments taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a perspective view illustrating a coil component of a first embodiment.

FIG. 2A is a front view of the coil component of the first embodiment, and FIG. 2B is a cross-sectional view taken along line II-II in FIG. 2A.

FIG. 3 is a schematic drawing schematically illustrating an effective magnetic path which generates in the coil

component of the first embodiment when the winding is energized, and the coil winding direction.

FIG. 4 is a perspective view of a coil component of a second embodiment.

FIG. 5A is a front view of the coil component of the second embodiment, and FIG. 5B is a cross-sectional view taken along line III-III in FIG. 5A.

FIG. 6 is a schematic drawing schematically illustrating an effective magnetic path which generates in the coil component of the second embodiment, when the winding is energized, and coil winding direction.

FIGs. 7A and 7B are drawings illustrating a plate member used for a top plate or a bottom plate, wherein FIG. 7A is a top view of the plate member, and FIG. 7B is a front view of the plate member.

FIGs. 8A and 8B are drawings illustrating a columnar component, wherein FIG. 8A is a top view of the columnar component, and FIG. 8B is a front view of the columnar component.

FIGs. 9A and 9B are drawings illustrating relations of DC current supplied to the coil component of the first embodiment and the coil component of the second embodiment, with inductance of the coil components, wherein FIG. 9A represents the case where the windings are connected in parallel, and FIG. 9B represents the case where the windings are connected in series.

FIGs. 10A and 10B are drawings illustrating a coil component of a third embodiment, wherein FIG. 10A is a front view of the coil component of the third embodiment, and FIG. 10B is a cross-sectional view taken along line IV-IV in FIG. 10A.

FIGs. 11A and 11B are drawings illustrating a coil component according to a modified example of the first embodiment, wherein FIG. 11A is a front view of the coil component of the modified example, and FIG. 11B is a cross-sectional view taken along line V-V in FIG. 11A.

FIG. 12 is a simplified circuit diagram illustrating an electric circuit of a forward converter.

FIG. 13 is a flow chart illustrating a method of manufacturing a choke coil.

DETAILED DESCRIPTION

[0019] The invention will now be described herein with reference to illustrative embodiments. Those skilled in the art will recognize that many alternative embodiments can be accomplished using the teaching of the present invention and that the invention is not limited to the embodiments illustrated for explanatory purposes. In all drawings, all similar components will be numbered identically to avoid repetitive explanation for simplicity.

<Configuration of First Embodiment>

[0020] A configuration of a first embodiment of the present invention will be explained referring FIG. 1 to FIG. 3.

[0021] FIG. 1 is a perspective view of a coil component 100 of the first embodiment.

[0022] FIG. 2A is a front view of the coil component 100, and FIG. 2B is a cross-sectional view taken along line II-II in FIG. 2A.

[0023] FIG. 3 is a schematic drawing schematically illustrating effective magnetic path M1 which generates in the coil component 100 when energized through a winding 120, and the direction of winding of the winding 120.

[0024] The coil component 100 according to the first embodiment of the present invention has an annular coil core 110, and the winding 120. The annular coil core 110 is composed of a material having a higher permeability than that of air. The winding 120 is wound around the coil core 110 in close proximity thereto. The coil component 100 is characterized in that a cross section of the coil core 110, which is taken orthogonally to the winding axis of the winding 120, deviates either towards the inner loop side or towards the outer loop side of the coil core 110.

[0025] In more detail, the coil core 110 is configured to form a ring, contributed by a pair of columnar parts 116, 118 respectively having a columnar shape and having side faces opposed to each other, and a pair of sandwiching parts (top plate 112 and bottom plate 114) supporting the pair of columnar parts 116, 118 so as to hold them in between, each of which forming one side of a square.

[0026] The winding 120 is spirally wound around each of the pair of columnar parts 116, 118, and the cross-sections of the pair of columnar parts 116, 118 deviates either towards the inner loop side or towards the outer loop side.

[0027] The coil component 100 in this embodiment will be explained assuming that the cross-section of the coil core 110 (columnar parts 116, 118) deviates towards the inner loop side, as illustrated in FIG. 2B.

[0028] As illustrated in FIG. 3, a winding 122 is wound clockwise when viewed from the top of the columnar part 116, and the winding 124 is wound counterclockwise when viewed from the top of the columnar part 118. Although not illustrated, each of the winding 122 and the winding 124 has a lead wire so as to be energized therethrough.

[0029] Between the columnar parts 116, 118 and the top plate 112, there is provided a resin film 130 composed of a resin having a lower permeability than that of the coil core 110, so as to form a so-called coil gap.

[0030] The permeability of the resin film 130 is preferably low enough to be assumed as air, as compared with the permeability of the coil core 110.

[0031] While the resin film 130 in this embodiment is positioned between the columnar parts 116, 118 and the top plate 112, it may alternatively be positioned between the columnar parts 116, 118 and the bottom plate 114, or between both of them.

[0032] The coil core 110 is inserted inside the coil (winding 120). The coil core is generally exemplified by those made of ceramics mainly composed of iron oxide (ferrite core), those made of amorphous alloy (amorphous core), those obtained by compression molding of metal powder (dust core), and those having a laminated structure of a plurality of electrical steel sheets which are electrically isolated from each other (laminated core).

[0033] The term of "annular" means a geometry which surrounds a certain area on a plane (circle, square, etc.), or, a geometry which surrounds a certain area on a plane but the contour of which has a partial omission (C-shape, U-shape, etc.). The omission herein is made only to a degree enough to allow the coil core 110 to configure a closed magnetic path. In other words, the site of omission functions as a coil gap of the coil core 110.

[0034] The term of "inner loop side" means the inner side of the direction in which a first portion and a second portion are opposed in the annular coil core 110. The term of "outer loop side" means the outer side of the direction in which a first portion and a second portion are opposed in the annular coil core 110.

[0035] The phrase of "a cross section deviates towards one side" means that the centroid of area deviates towards one side. More specifically, referring to the columnar parts 116, 118 of this embodiment, when the center of rigidity and the centroid of area of the cross section of the columnar parts 116, 118 are determined while assuming that the coil core 110 is composed of a single material, the cross section is then understood to deviate towards the inner loop side, if the center of rigidity falls more deeply in the outer loop side than the centroid of area is. On the other hand on the same assumption, the cross section is understood to deviate towards the outer loop side, if the center of rigidity of a cross section falls more deeply in the inner loop side in the opposing direction than the centroid of area is. The centroid of area may be determined as the center of gravity of the cross-sectional area, and the center of rigidity may be determined by dividing cross-sectional primary moment by the cross-sectional area.

[0036] Now the term of "columnar" means any of column-like shapes, and more specifically include a shape having the side circumferential surface which stands upright on an arbitrary plane, a shape having the side circumferential surface bulged at the middle thereof, a shape having the side circumferential surface thinned at the middle thereof, and a shape having the side circumferential surface which contains a projection or a recess.

[0037] The columnar parts 116, 118 in this embodiment can stand upright on the bottom plate 114 or the top plate 112, in both cases where the bottom plate 114 is placed on the lower side in the perpendicular direction, and where the top plate 112 is placed on the lower side in the perpendicular direction. In these cases, it suffices that the columnar parts 116, 118 stand upright on the bottom plate 114 or on the top plate 112 in the assembled coil core 110, or in the form of finished product, even if the columnar parts 116, 118 are not shaped in a self-supporting manner before the coil core 110 is assembled.

[0038] Now the term of "side circumferential surface" means a surface other than both end faces. The phrase of "having side circumferential surfaces opposed to each other" encompasses the case where there is a hollow space between both side circumferential surfaces, so that one side circumferential surface is directly visible from the other side circumferential surface, and the case where both surfaces are opposed to each other while holding in between some other member (encapsulating resin, for example).

[0039] The phrase of "in close proximity" encompasses both of "being brought into contact", and "being positioned nearby without being brought into contact".

[0040] In this embodiment, distance between the coil core 110 and the conductor part (coil) of the winding 120 is preferably minimized as possible. This is because the closer the positions comes to the coil, the stronger the magnetic field induced by current supply to the coil, and, the closer the coil core 110 comes to the coil, the more the magnetic flux which passes through the coil core 110, and thereby, the magnetic characteristics including inductance are improved when the coil component 100 as a whole is taken into account.

[0041] For the case where the specific resistance of material composing the coil core 110 is low (Mn-Zn-based ferrite core, for example), and the winding is wound in contact with the coil core 110, the coil core 110 and the coil would be short-circuited if the coating layer of winding should be broken by a flash produced at the edge of the core. In order to avoid such nonconformity, it may be necessary in some cases to preliminarily provide an insulating finish (forming a coating layer with a tape or resin, for example) over the surface of the coil core 110.

[0042] The phrase of "a pair of sandwiching parts (top plate 112 and bottom plate 114) holding in between the columnar parts 116, 118" means that the bottom face of the top plate 112, representing one surface of the sandwiching parts, is opposed to the top faces of the columnar parts 116, 118, and that the top face of the bottom plate 114, representing the other surface of the sandwiching parts, is opposed to the bottom faces of the columnar parts 116, 118, including both cases where the opposed faces are brought into contact, and where they are not brought into contact. In this embodiment, the case where the opposed faces are not brought into contact includes an exemplary case where a gap is provided in between.

[0043] The phrase of "a pair of sandwiching parts (top plate 112 and bottom plate 114) supporting the pair of columnar

parts 116, 118" means that the columnar parts 116, 118 are immobilized so as not to move relative to the sandwiching part (top plate 112 or bottom plate 114). A variety of embodiments are feasible as modes of supporting the columnar parts 116, 118. For example, the columnar parts 116, 118 may be fixed to the top plate 112 or the bottom plate 114 by adhesion, or by fitting. The columnar parts 116, 118 may alternatively be fixed using a clamp which keeps them in contact under pressure, on both of the top faces and bottom faces thereof, with the top plate 112 and the bottom plate 114. Alternatively, the columnar parts 116, 118, the top plate 112 and the bottom plate 114 may be arranged in a predetermined positional relation, followed by encapsulation with an insulating resin.

[0044] In FIG. 3, an effective magnetic path M1 of a coil component 200 is indicated by a broken line. As illustrated in the drawing, the effective magnetic path M1 which passes through the coil core 110 is routed so as to deviate from the center towards the inner loop side. As a result of deviation of the cross section of the coil core 110 towards the inner loop side of the coil core 110, magnetic flux which passes through the inner loop side of the coil core 110 increases, whereas the magnetic flux which passes through the outer loop side of the coil core 110 decreases. This is why the effective magnetic path M1 of the coil component 100 as a whole can deviate towards the inner loop side.

[0045] Inductance of an ideal coil is given by the equation (1) below:

[Mathematical Formula 1]

$$L = (\mu \cdot Ae \cdot N^2) / l \quad (1)$$

where, L represents inductance, l represents effective magnetic path length, Ae represents cross-sectional area of core, and μ represents permeability of core.

[0046] As given by the equation (1), the inductance of an ideal coil is inversely proportional to the effective magnetic path length. While the inversely proportional relation between the inductance and the effective magnetic path length in an actual coil may be disordered to some degree, it still remains that the shorter the effective magnetic path, the larger the inductance, and that the longer the effective magnetic path length, the smaller the inductance.

[0047] In the coil component 100 of this embodiment, since the effective magnetic path M1 is routed closer towards the inner loop side to thereby substantially shorten the effective magnetic path length as described above, so that the inductance will increase as compared with that of a coil component having equivalent levels of the individual parameters (core volume, core distance, core material, gap length, way of winding, number of turns), but no deviation.

[0048] The core volume means the volume of the coil core 110 *per se*.

[0049] The core distance means the distance between the inner-loop-side lateral face of the columnar part 116 and the inner-loop-side lateral face of the columnar part 118. The inner-loop-side lateral face means a part of the side circumferential surface of the coil core 110, which is placed on the inner loop side.

[0050] The core material means a material composing the coil core 110.

[0051] The way of winding means a way by which the winding 120 is wound around the columnar parts 116, 118, and specifically includes tension applied to the winding 120, and pitch of adjacent turns of the winding 120.

[0052] The number of turns means the number of times the winding 120 is wound around the columnar parts 116, 118.

[0053] The DC superimposition characteristic of the coil component 100 is predominantly determined by the structure of the coil core 110. More specifically referring to this embodiment, the DC superimposition characteristic of the coil component 100 is determined by parameters including cross-sectional area of the columnar parts 116, 118; distance between the columnar part 116 and the columnar parts 118; volume of the top plate 112 and the bottom plate 114; materials composing the top plate 112, the bottom plate 114 and the columnar parts 116, 118; gap length of the coil core 110 (thickness of the resin film 130); way of winding of the winding 120; and the number of turns of the winding 120. Of the parameters exemplified above, the number of winding of the winding 120 may be arbitrarily increased or decreased, where the upper limit of which is determined by the size and shape of the coil core 110.

[0054] Now, the coil component 100 of this embodiment is successfully increased in the inductance of the coil component 100, while focusing on the deviation of cross section of the coil core 110 (columnar parts 116, 118) which is not included in the parameters enumerated above, and therefore scarcely affects the DC superimposition characteristic.

[0055] General coil component is adjusted to satisfy desired levels of inductance and DC superimposition characteristic, by determining a material and a structure of the coil core based on a target inductance, and then by increasing or decreasing the number of turns or the gap length. The inductance and the DC superimposition characteristic are however in a trade-off relation, so that any change in the number of turns and the gap length for increasing either one will decrease the other.

[0056] Now according to the coil component 100 of this embodiment, it is possible to prepare the coil component which satisfies a target inductance without due consideration on the effect on the DC superimposition characteristic, so that it becomes easy to obtain desired levels of magnetic characteristics.

[0057] The phrase of "prepare the coil component" means to manufacture a coil component which satisfies desired specifications, by adjusting or selecting various parameters. More specifically, a possible embodiment is such as deriving a target value of a parameter, actually measuring the parameter of the coil component, increasing or decreasing the number of turns or the gap length of the coil core, which are alternately repeated as necessary, to thereby manufacture the coil component which satisfies the thus derived target value. Another possible embodiment is such as deriving a target value of a parameter, and selecting a coil component which satisfies the thus derived target value, out from a set of a plurality of coil components having different values of such parameter, to thereby manufacture the coil component.

[0058] In the coil component 100 of this embodiment, the columnar part 116 having the winding 122 round therearound, and the columnar part 118 having the winding 124 wound therearound are independent, and each of which is held between the pair of sandwiching parts (top plate 112 and bottom plate 114). With such configuration, the coil component 100 may be assembled after winding the windings 122, 124 around the columnar parts 116, 118. This enables machine-assisted automatic winding, and raises benefits of keeping the tension of the windings 122, 124 at constant during winding, and of reducing the time consumed for winding.

[0059] Since the columnar parts 116, 118 and the sandwiching parts (top plate 112 and bottom plate 114) in the coil component 100 of this embodiment are separate and independent members, so that it is now possible to select and use the columnar parts 116, 118 out from a series of columnar components having various degrees of deviation of the transverse cross-section. Accordingly, the inductance of the coil component 100 may be increased or decreased simply by replacement of the columnar parts 116, 118. From the viewpoint of the sandwiching parts, a material for composing the sandwiching parts may be standardized, and this successfully improves the productivity and consequently reduces cost of the coil component 100.

[0060] As illustrated in FIG. 2B, the columnar parts 116, 118 of this embodiment have a near-trapezoidal transverse cross-section. The columnar parts 116, 118 are arranged so as to direct the longest side, out of the sides of the transverse cross section of each of the columnar parts 116, 118, towards the inner loop side of the coil core 110. The columnar parts 116, 118 have nearly same shapes of the transverse cross-sections at all levels of height, and are respectively vertical to the bottom plate 114 and the top plate 112.

[0061] In short, the coil component 100 of this embodiment has structural features summarized below.

[0062] In one columnar part 116, the side circumferential surface includes at least one flat part, and, the largest flat part 117 having the largest area out of the flat parts included in the side circumferential surface is positioned on the inner loop side of the coil core 110, thereby making the cross section of the columnar part 116 deviate towards the inner loop side.

[0063] In the other columnar part 118, the side circumferential surface includes at least one flat part, and, the largest flat part 119 having the largest area out of the flat parts included in the side circumferential surface is positioned on the inner loop side, thereby making the cross section of the columnar part 118 deviate towards the inner loop side.

[0064] In other words, in the coil component 100 of this embodiment, the pair of columnar parts 116, 118 respectively have the largest flat parts 117, 119 on the inner loop side of the coil core 110, and the largest flat parts 117, 119 are arranged in parallel.

[0065] As illustrated in FIG. 1 and FIG. 2A, the coil core 110 of this embodiment has a square shape. In such square coil core 110 configured to direct either one of the largest flat part 117 and the largest flat part 119 towards the inner loop side of the coil core 110, the effective magnetic path length of the coil component 100 may be shortened, and thereby the inductance of the coil component 100 may be increased, in a more effective manner. In addition, by arranging the largest flat part 117 and the largest flat part 119 in parallel to each other on the inner loop side, the effective magnetic path length of the coil component 100 may become shortest, and the inductance of the coil component 100 may be increased.

[0066] The top plate 112 and the bottom plate 114 are configured by a pair of flat plates opposed in parallel to each other. In other words, the top plate 112 and the bottom plate 114 are opposed in parallel to each other, having no projection other than the columnar parts 116, 118 in the space held in between. The projection means a part projected from the top plate 112 and the bottom plate 114, and is composed of a material same as that composing the individual plates, or a material having an equivalent level of permeability.

[0067] Assuming now that at least either one of the top plate 112 and the bottom plate 114 has a projection on the opposing surface(s), such projection may deform the magnetic field formed between the top plate 112 and the bottom plate 114, and is capable of inhibiting the effect of this embodiment by shifting the magnetic path to be formed in the coil component 100 towards the outer loop side of the coil core 110. In short, a preferable configuration is such that, between the top plate 112 and the bottom plate 114, there is possibly no component with high permeability except for the columnar parts 116, 118.

[0068] The pair of columnar parts 116, 118 are preferably enclosed in the space formed between the opposing top plate 112 and bottom plate 114. Since the columnar part 116 has the winding 122, and the columnar part 118 has the winding 124, so as to be respectively wound around the side faces thereof in close proximity thereto, so that a magnetic field generates over the entire side face under current supply. Accordingly, with the configuration having the columnar part 116 and the columnar part 118 enclosed in the space formed between the opposing top plate 112 and the bottom

plate 114, it becomes now possible to avoid leakage of magnetic flux which passes through the columnar parts 116, 118, to thereby improve various magnetic characteristics of the coil component 100 as a whole, typified by increase in inductance.

[0069] Having described the configuration of this embodiment, the embodiment is merely an illustrative one of the present invention which may be configured in different ways.

[0070] For example, the columnar parts 116, 118, having a near-trapezoidal transverse cross-sectional shape in this embodiment, may have any other shape, so long as the shape deviates towards the inner loop side or the outer loop side of the coil core 110. Shape to be adopted is selectable from a wide variety of shapes including polygons such as triangle, pentagon or the like; semicircle and arc; convex shape and concave shape; and shapes surrounded only by a curve and deviates towards one side.

[0071] While the columnar part 116 and the columnar part 118 have been illustrated in this embodiment, such that they are arranged symmetrically around the center of the transverse cross section of the coil component 100, they may alternatively be arranged asymmetrically.

<Configuration of Second Embodiment>

[0072] A second embodiment of the present invention will be explained referring to FIG. 4 to FIG. 6.

[0073] FIG. 4 is a perspective view illustrating a coil component 200 of the second embodiment.

[0074] FIG. 5A is a front view of the coil component 200, and FIG. 5B is a cross-sectional view taken along line III-III in FIG. 5A.

[0075] FIG. 6 is a schematic drawing schematically illustrating an effective magnetic path M2 induced in the coil component 200 when the winding 220 is energized, and the direction of winding of the winding 220.

[0076] The coil component 200 according to the second embodiment of the present invention has an annular coil core 210, a winding 220, and a resin film 230. The coil core 210 has a top plate 212, a bottom plate 214, a columnar part 216, and a columnar part 218.

[0077] The columnar part 216 has a winding 222 wound therearound, and the columnar part 218 has a winding 224 wound therearound. As illustrated in FIG. 6, the winding 222 is wound clockwise when viewed from the top of the columnar part 216, and the winding 224 is wound counterclockwise when viewed from the top of the columnar part 218.

[0078] Although not illustrated, each of the winding 222 and the winding 224 has a lead wire so as to be energized therethrough.

[0079] The coil core 210 and the coil core 110 in the first embodiment, the winding 220 and the winding 120 in the first embodiment, and the resin film 230 and the resin film 130 in the first embodiment, are respectively composed of the same materials.

[0080] The top plate 212 and the bottom plate 214 may be configured by a material same as that used for the top plate 112 and the bottom plate 114 in the first embodiment.

[0081] The coil component 200 of this embodiment is now different from the coil component 100 of the first embodiment, in that, as illustrated in FIG. 5B, the cross section of the coil core 210 (columnar parts 216, 218) deviates towards the outer loop side.

[0082] In FIG. 6, an effective magnetic path M2 of the coil component 200 is indicated by a broken line. As illustrated here, in the coil component 200 of this embodiment, the effective magnetic path M2 which passes through the coil core 210 is routed so as to deviate from the center towards the outer loop side. In other words, the cross section of the coil core 210 deviates towards the outer loop side of the coil core 210. Accordingly, the magnetic flux which passes through the outer loop side of the coil core 210 increases, whereas the magnetic flux which passes through the inner loop side of the coil core 210 decreases. This is why the effective magnetic path M2 of the coil component 200 as a whole can deviate towards the outer loop side.

[0083] In the coil component 200 of this embodiment, since the effective magnetic path length is substantially elongated, so that the inductance will decrease as compared with that of a coil component having equivalent levels of the individual parameters (core volume, core distance, core material, gap length, way of winding, number of turns), but no deviation.

[0084] In short, the coil component 200 of this embodiment has structural features summarized below.

[0085] In one columnar part 216, the side circumferential surface includes at least one flat part, and the largest flat part 217 having the largest area out of the flat parts included in the side circumferential surface, is positioned on the outer loop side of the coil core 210, thereby making the cross section of the columnar part 216 deviate towards the outer loop side.

[0086] In the other columnar part 218, the side circumferential surface includes at least one flat part, and the largest flat part 219 having the largest area out of the flat parts included in the side circumferential surface, is positioned on the outer loop side of the coil core 210, thereby making the cross section of the columnar part 218 deviate towards the outer loop side.

[0087] In other words, in the coil component 200 of this embodiment, the pair of columnar parts 216, 218 respectively

have the largest flat parts 217, 219 on the outer loop side of the coil core 210, and the largest flat parts 217, 219 are arranged in parallel.

[0088] As illustrated in FIG. 4 and FIG. 5A, the coil core 210 of this embodiment has a square shape. In such square coil core 210 configured to direct either one of the largest flat part 217 and the largest flat part 219 towards the outer loop side of the coil core 210, the effective magnetic path length of the coil component 200 may be elongated, and thereby the inductance of the coil component 200 may be decreased, in a more effective manner. In addition, by arranging the largest flat part 217 and the largest flat part 219 in parallel to each other on the outer loop side, the effective magnetic path length of the coil component 200 may become longest, and the inductance of the coil component 200 may be decreased.

<Evaluation Tests on First Embodiment and Second Embodiment>

[0089] Evaluation Tests on the magnetic characteristics of the coil component 100 according to the first embodiment, and on the magnetic characteristics of the coil component 200 of the second embodiment will be explained referring to FIG. 7A to FIG. 9B.

[0090] FIGs. 7A and 7B are drawings illustrating a plate member 12 used for composing the top plates 112, 212 or the bottom plates 114, 214. FIG. 7A is a top view of the plate member 12, and FIG. 7B is a side elevation of the plate member 12.

[0091] FIGs. 8A and 8B are drawings illustrating a columnar component 16 used for composing the columnar parts 116, 118, 216, 218. FIG. 8A is a top view of the columnar component 16, and FIG. 8B is a side elevation of the columnar component 16.

[0092] FIGs. 9A and 9B are drawings illustrating relations of DC current supplied to the coil components 100, 200, with inductance of the coil components. FIG. 9A represents the case where the windings 122, 124, or the windings 222, 224 are connected in parallel, and FIG. 9B represents the case where the windings 122, 124 or the windings 222, 224 are connected in series.

[0093] As illustrated in FIG. 7, the plate member 12 viewed from the top is a square plate 62 mm on a side, with a thickness of 16 mm.

[0094] As illustrated in FIG. 8, the columnar component 16 viewed from the top has a near-trapezoidal shape, and in more detail, has a shape derived from a trapezoid with the bases of 31 mm and 51 mm, and a height of 20 mm, by round chamfering at both ends of the individual bases. The columnar component 16 is 20 mm thick.

[0095] A material for composing both of the plate member 12 and the columnar component 16, used here is an Mn-Zn-based ferrite material called ML24D.

[0096] As illustrated in FIG. 8A, the cross-sectional shape of the columnar component 16 is a near polygon chamfered at the corner parts 15, 17, and more specifically a near trapezoid.

[0097] The size of chamfering at the corner part 17, positioned on the side to which the cross section of the columnar component 16 deviates, is smaller than the size of chamfering at the corner part 15 positioned on the opposite side. In more detail, the corner part 15 is round chamfered to a radius of 10 mm, and the corner part 17 is round chamfered to a radius of 6 mm. Having exemplified the case of round chamfering (rounding), the chamfering may alternatively be 45° chamfering (corner chamfering).

[0098] By chamfering the corner parts 15, 17 of the columnar component 16, the winding (for example, windings 122, 124, and windings 222, 224) may be wound around the columnar component 16 in a more strongly adherent manner. In this way, it becomes now possible to avoid leakage of magnetic flux from the columnar component 16, and to thereby improve various magnetic characteristics of the coil component (for example, coil component 100 and coil component 200) as a whole, typified by increase in inductance.

[0099] Since the radius of round chamfering at the corner part 17 is smaller than the radius of round chamfering at the corner part 15, the flat part (largest flat part 117 and largest flat part 217) on the side of deviation will have a less area of removal by chamfering at both ends thereof in the direction of circumferential surface. This way of round chamfering will therefore intensify the effect of the present invention, aimed at shifting the effective magnetic path produced in the coil device towards the side to which the cross section of the coil core deviates.

[0100] The coil component 100 of the first embodiment and the coil component 200 of the second embodiment were manufactured by combining the plate member 12 and the columnar component 16 respectively illustrated in FIGs. 7A, 7B and FIGs. 8A, 8B.

[0101] The windings 120, 220 used herein was 1 mm in diameter, and the number of turns was 40. The gap length (thickness of the resin films 130, 230) was 1 mm. The plate member 12 and the columnar component 16 were arranged while placing in between a spacer of 11.7 mm thick (not illustrated). Frequency of measurement was set to 100 kHz.

[0102] It is found from FIGs. 9A, 9B that the coil component 100 shows larger inductance than that of the coil component 200, in both cases of parallel connection and series connection. Difference in inductance between the coil component 100 and the coil component 200 was found to be approximately 4%.

[0103] As for the DC superimposition characteristic, both of the coil component 100 and the coil component 200 were found to decrease in inductance to an equivalent degree.

[0104] In short, it was evaluated that the inductance was successfully increased or decreased by changing the cross-sectional shape of the coil cores 110, 210. It was also evaluated that such change was found to scarcely affect the DC superimposition characteristic, when other parameters (core volume, core distance, core material, gap length, way of winding, the number of turns) remained unchanged.

<Third Embodiment>

[0105] A third embodiment of the present invention will be explained referring to FIGs. 10A, 10B.

[0106] FIGs. 10A, 10B are drawings illustrating a coil component 300 of the third embodiment. FIG. 10A is a front view of the coil component 300, and FIG. 10B is a cross-sectional view taken along line IV-IV in FIG. 10A.

[0107] As seen in FIG. 10A, the coil core 310 has a form of bent rod, and the cross section thereof deviates towards at least one of the inner side or outer side of the bending curvature of the coil core 310. In this point of view, the coil component 300 of the third embodiment is different from the coil component 100 of the first embodiment and the coil component 200 of the second embodiment. More specifically, the coil core 300 of this embodiment is a single-component toroidal core composed of a doughnut-shaped (annular) member.

[0108] The term "bent" not only relates to the doughnut-shaped mode illustrated above, but also relates to a mode of bending once in the middle way (L-shaped), a mode of bending twice in the middle way in the same direction (U-shaped), and a mode of bending like a bow. It is not always necessary for the coil core 310 to be configured by a single component, and may instead be configured by linking a plurality of components.

[0109] The coil component 300 of the third embodiment is different from the above-described embodiments, in that the winding 320 wound around the coil core 310 is a single wire component, and is wound over almost entire side circumferential surface of the rod-like coil core 310.

[0110] However, from the viewpoint of electric circuit, this is understood to be equivalent to a configuration having a plurality of windings (for example, the winding 122 and the winding 124 in the first embodiment) connected in series.

[0111] While the winding 320 will be explained hereafter as a single entirety, the winding 320 may be configured by a plurality of components, which may occasionally be connected in parallel.

[0112] The coil gap 330 is not limited to a vacancy, but may be filled with some material (resin, for example) having permeability sufficiently smaller than that of the coil core 310. It is not always necessary to provide the coil gap 330, and the coil core 310 in this case may have a form of continuous perfect circle, rectangle, ellipse, or the like.

[0113] As illustrated in FIG. 10B, the coil component 300 of the third embodiment is similar to the coil component 100 of the first embodiment, in terms that a cross section of the coil core 310, which is taken orthogonally to the winding axis of the winding 320, deviates towards the inner loop side of the coil core 310. In other words, the coil core 310 is made thicker in the inner loop side, than in the outer loop side. Now the thickness of the coil core 310 means the depth size of the coil core 310 in the direction the coil core 310 looks like a doughnut, that is, the depth size of the coil core 310 in a view as illustrated in FIG. 10A.

[0114] Having features equivalent to those of the coil component 100, also the coil component 300 successfully increases in the inductance, as compared with coil components with equivalent parameters (core volume, core distance, core material gap length, way of winding, and the number of turns), but no deviation.

[0115] The coil component 300 having a so-called toroidal core causes less leakage of magnetic flux, and consequently has larger inductance as compared with coil components (coil component 100, for example) having equivalent levels of the individual parameters (core volume, core distance, core material, gap length, way of winding, and the number of turns).

[0116] The paragraphs above explained the embodiment in which the coil core 310 is made thicker on the inner loop side thereof, than on the outer loop side. In another possible modified example this embodiment, the coil core 310 may be made thicker on the outer loop side thereof, than on the inner loop side. Reduced inductance of this modified example, as compared with the third embodiment, is clearly understood from the principle explained by comparison between the coil component 100 and the coil component 200.

[0117] While the nearly trapezoidal cross section of the coil core 310 was illustrated in FIG. 10B merely as an example, the cross section may be varied in various ways, similarly to the cross-sectional shape of the columnar parts 116, 118 in the first embodiment.

<Modified Example of First Embodiment>

[0118] A modified example of the first embodiment of the present invention will be explained referring to FIGs. 11A, 11B.

[0119] FIGs. 11A, 11B are drawing illustrating a coil component 400 of the modified example of the first embodiment. FIG. 11A is a front view of the coil component 400, and FIG. 11B is a cross-sectional view taken along line V-V in FIG. 11A.

[0120] The coil component 400 of the modified example has an annular coil core 410, a winding 420, and a resin film

430. The coil core 410 has a top plate 412, a bottom plate 414, a columnar part 416, and a columnar part 418. The columnar part 416 has a winding 422 wound therearound, and the columnar part 418 has a winding 424 wound therearound.

[0121] Although not illustrated here, similarly to the coil component 100 of the first embodiment, the winding 422 is wound clockwise when viewed from the top of the columnar part 416, and the winding 424 is wound counterclockwise when viewed from the top of the columnar part 418.

[0122] Although not illustrated here, each of the winding 422 and the winding 424 has a lead wire so as to be energized therethrough.

[0123] The coil core 410 and the coil core 110 in the first embodiment, the winding 420 and the winding 120 in the first embodiment, and the resin film 430 and the resin film 130 in the first embodiment, are respectively composed of the same materials.

[0124] The top plate 412 and the bottom plate 414 is configured by a material same as that used for the top plate 112 and the bottom plate 114 in the first embodiment.

[0125] As illustrated in FIG. 11A, the coil component 400 is different from the coil component 100 of the first embodiment, in that the columnar parts 416, 418 are apart from the sandwiching part (top plate 412), wherein the distance of the columnar parts 416, 418 away from the top plate 412, on the side towards which the cross section of the columnar parts 416, 418 deviates, is larger than the distance of the columnar parts 416, 418 away from the top plate 412 on the opposite side.

[0126] The resin film 430 provided so as to extend between the columnar parts 416, 418 and the top plate 412 has a wedge-like shape. Now the wedge-like shape means a shape thickened on one end, and gradually thinned towards the other end.

[0127] In more detail, the coil component 400 of this modified example is different from the coil component 100 of the first embodiment, in that the cross section of the columnar parts 416, 418 deviates towards the inner loop side, and, the distance away from the top plate 412 is larger on the inner loop side, than on the outer loop side.

[0128] In other words, the resin film 430 provided so as to extend between the columnar parts 416, 418 and the top plate 412 is thick on one end positioned on the inner loop side, and is gradually thinned towards the other end positioned on the outer loop side.

[0129] With such structural features, the coil component 400 of this modified example successfully acquires a so-called swinging characteristic. The swinging characteristic means a characteristic of coil capable of ensuring a relatively large inductance when a small current flows through the winding, whereas capable of keeping a nearly constant inductance even when the current increases.

[0130] The swinging characteristic is aimed at preventing intermittent oscillation, mainly in a choke coil used for high-frequency switching power circuit.

[0131] For the case where the wedge-like coil gap is provided to general coil components with symmetrical cross-sections of the coil cores, aiming at achieving the swinging characteristic, the characteristic will not largely vary depending on whichever part of the coil gap is thickened (or thinned). On the other hand, the coil component 400 of this modified example will largely vary the characteristic depending on whichever part thereof is thickened (or thinned).

[0132] As in the coil component 400 of this modified example, by providing the coil gap so as to be thickened (expanding the distance) on the side towards which the transverse cross-sections of the columnar parts 416, 418 deviate (the inner loop side of the coil core 410), the permeability will decrease on the inner loop side through which the magnetic flux passes more densely, so that the swinging characteristic may be more distinctive than in the general coil components, and thereby the DC superimposition characteristic may be improved.

[0133] Since the coil component 400 of this modified example is configured to have a small coil gap (distance) on the outer loop side of the coil core 410, so that an additional effect obtainable now is reduced leakage of magnetic flux outward from the coil component 400.

[0134] While the description in this modified example was made on the case where the core gap is thickened on the side towards which the transverse cross-sections of the columnar parts 416, 418 deviate, the present invention is not limited thereto. For example, another possible embodiment is such as thinning the coil gap on the side towards which the transverse cross-sections of the columnar parts 416, 418 deviate. In this case, the permeability becomes high on the inner loop side through which the magnetic flux passes more densely, so that a large inductance may be obtained in the small current region.

[0135] While the description in this modified example was made on the coil component 400 which represents the modified example of the first embodiment, it is also possible without limitation to configure a coil component by providing the swinging characteristic to the coil component 200 of the second embodiment. More specifically, in another possible embodiment, the cross section of the columnar part may deviate towards the outer loop side, and, the distance between the columnar part and the sandwiching part (top plate or bottom plate) may be larger on the outer loop side, than on the inner loop side.

[0136] Having explained the wedge-like shape, the coil gap (resin film 430) may have a variety of shapes without

being limited thereto. For example, the distance may be different between the inner loop side and the outer loop side of the coil core 410, by forming the top faces of the columnar parts 416, 418 into a stepwise pattern in the front view.

[0137] The coil components of the present invention were explained referring to a variety of embodiments and modified examples, merely for illustrative purposes. Various constituents of the present invention are not always necessarily be independent from each other, and instead embrace various cases including that a plurality of constituents configure a single member, a single constituent is configured by a plurality of members, a certain constituent forms a part of other constituent, and a part of a certain constituent is shared with a part of other constituent.

[0138] The various constituents of the present invention do not exclude providing an unillustrated hole, slit, or the like depending on needs.

<Coil Component Set>

[0139] A coil component set having a plurality of coil components according to the above-described various embodiments and modified examples will be explained.

[0140] That is, the coil component set contains a plurality of coil components (coil component 100 and coil component 200, for example) which respectively have the annular coil cores (coil core 110 and coil core 210, for example) composed of a material having a higher permeability than that of air, and the windings (winding 120 and winding 220, for example) wound around the coil cores in close proximity thereto.

[0141] In the coil component set, the plurality of coil components have equivalent levels of either one of inductance and DC superimposition characteristic. Of the plurality of coil components contained in the coil component set, a cross section of the coil core in a first coil component, which is taken orthogonally to the winding axis of winding, deviates either towards the inner loop side or towards the outer loop side of the coil core, more largely as compared with the cross section of the coil core in a second coil component.

[0142] Besides the various coil components described above, the coil component set may contain any other coil components having symmetrical cross section of the coil core. That is, what is essential is that, when the cross-sections of the plurality of coil components are compared in shape, the one deviates more largely than another, without absolutely needing that the cross section of the coil core deviates within a single coil component.

[0143] Assuming now the coil component set is composed of the plurality of coil components having equivalent levels of the individual parameters (core volume, core distance, core material, gap length, way of winding, and the number of turns) and featured as described above, the plurality of coil components contained in such coil component set will be given an equivalent level of DC superimposition characteristic and a different level of inductance.

[0144] Assuming now the coil component set is composed of the plurality of coil components which differs in at least one of the above-described parameters, in particular in core material, gap length or the number of turns, and featured as described above, the plurality of coil components contained in such coil component set will be given an equivalent level of inductance and a different level of DC superimposition characteristic.

<Method of Manufacturing Coil Component>

[0145] The paragraphs below will describe a method of manufacturing the above-explained coil components of the various embodiments and modified examples. This is a method of manufacturing a coil component (for example, coil component 100 and coil component 200) having an annular coil core (coil core 110 and coil core 210, for example) composed of a material having a higher permeability than that of air, and a winding (winding 120 and winding 220, for example) wound around the coil core in close proximity thereto.

[0146] The method includes a step of derivation, a step of shape determination, and a step of molding. In the step of derivation, the degree of deviation of a cross section of the coil core, which is taken orthogonally to the winding axis of winding, either towards the inner loop side or towards the outer loop side of the coil core, is derived based on a desired inductance of the coil component. In the step of shape determination, a shape of the coil core is determined according to the degree derived in the step of derivation. In the step of molding, the coil component is molded according to the shape of coil core determined in the step of shape determination.

[0147] For more detailed explanation, assumed now is manufacturing of a choke coil L_1 used for a secondary smoothing circuit RF of a forward converter. Note that the method of manufacturing described below is merely an illustrative one, by no means limiting the present invention.

[0148] FIG. 12 is a simplified circuit diagram illustrating an electric circuit of a forward converter.

[0149] FIG. 13 is a flow chart illustrating a method of manufacturing the choke coil L_1 .

[0150] As illustrated in FIG. 12, AC power supplied from an AC power source AC is converted by an AC/DC converter (indicated as A/D in FIG. 12) to DC power, and then applied to a switching transistor Tr_1 . An input capacitor C_{in} is provided for the purpose of smoothing the input voltage. The switching transistor Tr_1 is switched by a control circuit CC according to a predetermined cycle, so as to convert the DC power into a high-frequency power of several tens kHz or higher. The

high-frequency power converted by the switching transistor Tr_1 is then converted by a transformer T_1 into desired levels of voltage and current. By contribution of a diode $D1$ and a diode Dr , surge current which generates when the switching transistor Tr_1 is turned OFF does not flow through the transformer T_1 , but is circulated in the output side.

[0151] Voltage and current converted by the transformer T_1 will have ripples superimposed thereon. In order to rectify and smoothen the waveform, a smoothing circuit RF is provided on the secondary side of the transformer T_1 . A circuit indicated by a broken line in FIG. 12 represents the smoothing circuit RF. The smoothing circuit RF is composed of a choke coil L_1 and a capacitor C_1 . Since the smoothing circuit RF is aimed at attenuating the ripples, so that the inductance of the choke coil L_1 should be one of important parameters, but also DC superimposition characteristic is important. That is, it is important for the choke coil L_1 to function as a coil, even under the maximum current which possibly flows therethrough.

[0152] If the choke coil magnetically saturates to no longer work as a coil, the smoothing circuit RF becomes incapable of rectification and smoothing, and thereby becomes incapable of stable power supply as the forward converter.

[0153] In the forward converter illustrated in FIG. 12, the inductance of the choke coil L_1 is given by the equation (2) below.

[Mathematical Formula 2]

$$L_1 = \frac{V_S - V_O}{\Delta I_L} \cdot t_{ON} \quad (2)$$

In the equation (2),

L_1 : inductance of choke coil L_1 ;

V_S : secondary winding voltage of transformer T_1 ;

V_O : output voltage of forward converter;

ΔI_L : allowable ripple current; and

t_{ON} : ON time of switching transistor.

[0154] In a switching power circuit, the maximum current $I_{L(MAX)}$ which flows through the choke coil L_1 is determined taking operational conditions of a protection circuit (not illustrated) into consideration. Now the protection circuit means a circuit for monitoring voltage, current, etc. of a main circuit, and for stopping, upon detection of abnormality such as overload, overvoltage or the like, the inverter in order to prevent damages to the inverter and induction motor, or for controlling the voltage or current. The maximum current $I_{L(MAX)}$ is determined additionally taking allowable ripple current ΔI_L into consideration.

[0155] Assuming now the operational conditions of the protection circuit is 1.2 times of the rated output current I_O , and the allowable ripple current ΔI_L is 30%_{P.P} (15% in terms of DC output), the maximum current $I_{L(MAX)}$ is given by the equation (3) below.

[Mathematical Formula 3]

$$I_{L(MAX)} = I_O \times 1.2 \times 1.15 = I_O \times 1.38 \quad (3)$$

[0156] As illustrated in FIG. 13, manufacture of the choke coil L_1 starts from calculating a desired inductance of the choke coil L_1 using the equation (2) (step S1).

[0157] Next, the maximum current $I_{L(MAX)}$ necessary for keeping the desired DC superimposition characteristic of the choke coil L_1 , or the inductance found in step S1, is calculated using the equation (3) (step S2).

[0158] Based on the desired DC superimposition characteristic determined in step S2, the individual parameters of the choke coil L_1 (core volume, core distance, core material, gap length, way of winding, the number of turns, for example) are determined (step S3).

[0159] In step S3, another possible embodiment is, for example, such as roughly estimating the individual parameters (core volume, core distance, core material, gap length, way of winding, the number of turns, for example) based on the DC superimposition characteristic determined in step S2 and the desired inductance determined in step S1. Now the phrase of "roughly estimating" embraces determining a desired value with a certain numerical range, and, limiting a large number of choices into a predetermined number of choices.

[0160] In step S3, still another possible embodiment is such as, for example, choosing a coil component set which contains a plurality of the above-described embodiments and modified examples, which satisfy the desired DC super-

imposition characteristic determined in step S2.

[0161] Based on the desired inductance determined in step S1, the degree of deviation of the cross section of the coil core in the choke coil L_1 either towards the inner loop side or towards the outer loop side of the coil core (referred to as the degree of deviation, hereinafter) is derived (step S4, step of derivation).

[0162] Based on the degree of deviation derived in step S4, the shape of the coil core is determined (step S5, step of shape determination).

[0163] The choke coil L_1 is molded according to the shape of the coil core determined in step S5 (step S6, step of molding).

[0164] In step S4, a possible embodiment is such as, for example, calculating the degree of deviation, based on the individual parameters determined in step S3, and the desired inductance determined in step S₁. For the calculation, an equation (empirical equation) which depicts a relation among the degree of deviation, the individual parameters and the inductance, obtained after repetitive experiments may be used.

[0165] In step S5, a possible embodiment is such as, for example, determining the shape of the coil core, based on the individual parameters roughly estimated in step S3, and the degree of deviation derived in step S4.

[0166] As an embodiment implementing step S4 and step S5 in combination, another possible embodiment is such as, for example, choosing a coil component having a desired inductance, among from the coil component set selected in step S3.

[0167] In step S6, a possible embodiment is such as, for example, molding the coil component by placing ferrite particles into a mold corresponded to a shape determined in step S5. Alternatively, another possible embodiment is such as molding the coil component by grinding a base coil core into the shape determined in step S5.

[0168] While the paragraphs above have described the method of manufacturing a coil component of the present invention, assuming the case of manufacturing the choke coil L_1 used for the secondary smoothing circuit RF of the forward converter, the present invention is also applicable to a method of manufacturing a coil component used for other purposes.

[0169] For example, the present invention is also applicable to manufacture of a transformer used for flyback converter for PWM control. In this case, the coil component has a plurality of windings (for example, the winding 122 and the winding 124 of the coil component 100) independent from each other, wherein the one is used as the primary winding, and the other is used as the secondary winding.

[0170] The transformer is used according to the PWM system (continuous conduction mode), and necessarily has a large inductance than that of transformer used according to the RCC system (boundary conduction mode). While a desired inductance is achieved generally by reducing the gap length, this has consequently degraded the DC superimposition characteristic, and has sometimes failed in satisfying the desired specification.

[0171] On the contrary, According to the method of manufacturing a coil component of the present invention, the inductance may be increased or decreased by increasing or decreasing the degree of deviation of the cross section of the coil core, while keeping the DC superimposition characteristic almost unchanged. A desired inductance is therefore achieved easily.

[0172] In short, the method of manufacturing a coil component of the present invention is preferably applicable to the coil component for which the inductance has been adjustable only with difficulty by the general method of adjusting inductance (for example, increasing or decreasing the number of turns, or increasing or decreasing the gap length), due to the trade-off relation between inductance and DC superimposition characteristic.

[0173] This embodiment embraces the technical spirits below:

(1) A coil component which includes: an annular coil core composed of a material having a higher permeability than that of air; and a winding wound around the coil core in close proximity thereto, characterized in that the coil component further comprises: a cross section of the coil core, which is taken orthogonally to the winding axis of winding, deviating either towards the inner loop side or towards the outer loop side of the coil core.

(2) The coil component according to (1), wherein the coil core is configured into a square loop, the sides of which being configured by: a pair of columnar parts which respectively have a columnar shape and have the side circumferential surfaces opposed to each other; and a pair of sandwiching parts which support the pair of columnar parts so as to hold them in between, the winding is wound respectively around each of the pair of columnar parts, each of the pair of columnar part having a cross section which deviates either towards the inner loop side or towards the outer loop side.

(3) The coil component according to (2), wherein in one of the columnar parts, the side circumferential surface includes at least one flat part, and the cross section deviates either towards the inner loop side or towards the outer loop side, as a result of placement of the largest flat part, having the largest area among the flat parts included in the side circumferential surface, on the inner loop side or on the outer loop side.

(4) The coil component according to (3), wherein the cross-sectional shape is a near polygon with chamfered corner parts, and the size of chamfering of the corner part positioned on the side to which the cross section deviates is

smaller than the size of chamfering of the corner part positioned on the opposite side.

(5) The coil component according to (3) or (4), wherein each of the pair of columnar parts has the largest flat part on the inner loop side, and both largest flat parts are arranged in parallel.

(6) The coil component according to (3) or (4), wherein each of the pair of columnar part has the largest flat part on the outer loop side, and both largest flat parts are arranged in parallel.

(7) The coil component according to any one of (2) to (6), wherein the columnar parts and the sandwiching parts are kept apart, and the distance between the columnar parts and the sandwiching parts is larger on the side to which the cross section of the columnar part deviates, than on the opposite side.

(8) The coil component according to (7), wherein the cross section deviates towards the inner loop side, and the distance is larger on the inner loop side than on the outer loop side.

(9) The coil component according to (1), wherein the coil core has a bent rod form, and the cross section deviates to at least either towards the inner side or towards the outer side of the bending curvature of the coil core.

(10) A method of manufacturing a coil component having an annular coil core composed of a material having a higher permeability than that of air, and a winding wound around the coil core in close proximity thereto, characterized in that the method includes: deriving the degree of deviation of a cross section of the coil core, which is taken orthogonally to the winding axis of winding, either towards the inner loop side or towards the outer loop side of the coil core, based on a desired inductance of the coil component; determining a shape of the coil core, according to the degree derived in the preceding step of derivation; and molding the coil component, according to the shape of coil core determined in the preceding step of shape determination.

(11) A coil component set comprising a plurality of coil components each having an annular coil core composed of a material having a higher permeability than that of air, and a winding wound around the coil core in close proximity thereto, and, among the plurality of coil components having equivalent levels of either one of inductance and DC superimposition characteristic, a cross section of the coil core in a first coil component, which is taken orthogonally to the winding axis of winding, deviating either towards the inner loop side or towards the outer loop side of the coil core, more largely as compared with the cross section of the coil core in a second coil component.

(a) The coil component according to any one of (2) to (8), wherein the pair of sandwiching parts are configured by a pair of flat plates opposed in parallel to each other.

(b) The coil component according to (a), wherein the pair of columnar parts are contained in a space formed between the pair of opposing flat plates.

[0174] It is apparent that the present invention is not limited to the above embodiments, and may be modified and changed without departing from the scope and spirit of the invention.

Claims

1. A coil component comprising:

an annular coil core composed of a material having a higher permeability than that of air; and
a winding wound around the coil core in close proximity thereto,
characterized in that the coil component further comprises:

a cross section of the coil core, which is taken orthogonally to the winding axis of winding, deviating either towards the inner loop side or towards the outer loop side of the coil core.

2. The coil component according to Claim 1, wherein the coil core is configured into a square loop, the sides of which being configured by:

a pair of columnar parts which respectively have a columnar shape and have the side circumferential surfaces opposed to each other; and
a pair of sandwiching parts which support the pair of columnar parts so as to hold them in between,

the winding is wound respectively around each of the pair of columnar parts, each of the pair of columnar part having a cross section which deviates either towards the inner loop side or towards the outer loop side.

3. The coil component according to Claim 2, wherein in one of the columnar parts, the side circumferential surface includes at least one flat part, and the cross

section deviates either towards the inner loop side or towards the outer loop side, as a result of placement of the largest flat part, having the largest area among the flat parts included in the side circumferential surface, on the inner loop side or on the outer loop side.

- 5 **4.** The coil component according to Claim 3,
wherein the cross-sectional shape is a near polygon with chamfered corner parts, and the size of chamfering of the corner part positioned on the side to which the cross section deviates is smaller than the size of chamfering of the corner part positioned on the opposite side.
- 10 **5.** The coil component according to Claim 3 or 4,
wherein each of the pair of columnar parts has the largest flat part on the inner loop side, and both largest flat parts are arranged in parallel.
- 15 **6.** The coil component according to Claim 3 or 4,
wherein each of the pair of columnar part has the largest flat part on the outer loop side, and both largest flat parts are arranged in parallel.
- 20 **7.** The coil component according to any one of Claims 2 to 6,
wherein the columnar parts and the sandwiching parts are kept apart, and the distance between the columnar parts and the sandwiching parts is larger on the side to which the cross section of the columnar part deviates, than on the opposite side.
- 25 **8.** The coil component according to Claim 7,
wherein the cross section deviates towards the inner loop side, and
the distance is larger on the inner loop side than on the outer loop side.
- 30 **9.** The coil component according to Claim 1,
wherein the coil core has a bent rod form, and the cross section deviates to at least either towards the inner side or towards the outer side of the bending curvature of the coil core.
- 35 **10.** A method of manufacturing a coil component having an annular coil core composed of a material having a higher permeability than that of air, and a winding wound around the coil core in close proximity thereto,
characterized in that the method comprising:
 - 35 deriving the degree of deviation of a cross section of the coil core, which is taken orthogonally to the winding axis of winding, either towards the inner loop side or towards the outer loop side of the coil core, based on a desired inductance of the coil component;
 - 40 determining a shape of the coil core, according to the degree derived in the preceding step of derivation; and
 - 40 molding the coil component, according to the shape of coil core determined in the preceding step of shape determination.
- 45 **11.** A coil component set comprising a plurality of coil components each having an annular coil core composed of a material having a higher permeability than that of air, and a winding wound around the coil core in close proximity thereto,
and,
among the plurality of coil components having equivalent levels of either one of inductance and DC superimposition characteristic,
a cross section of the coil core in a first coil component, which is taken orthogonally to the winding axis of winding,
deviating either towards the inner loop side or towards the outer loop side of the coil core, more largely as compared
50 with the cross section of the coil core in a second coil component.

Fig. 1

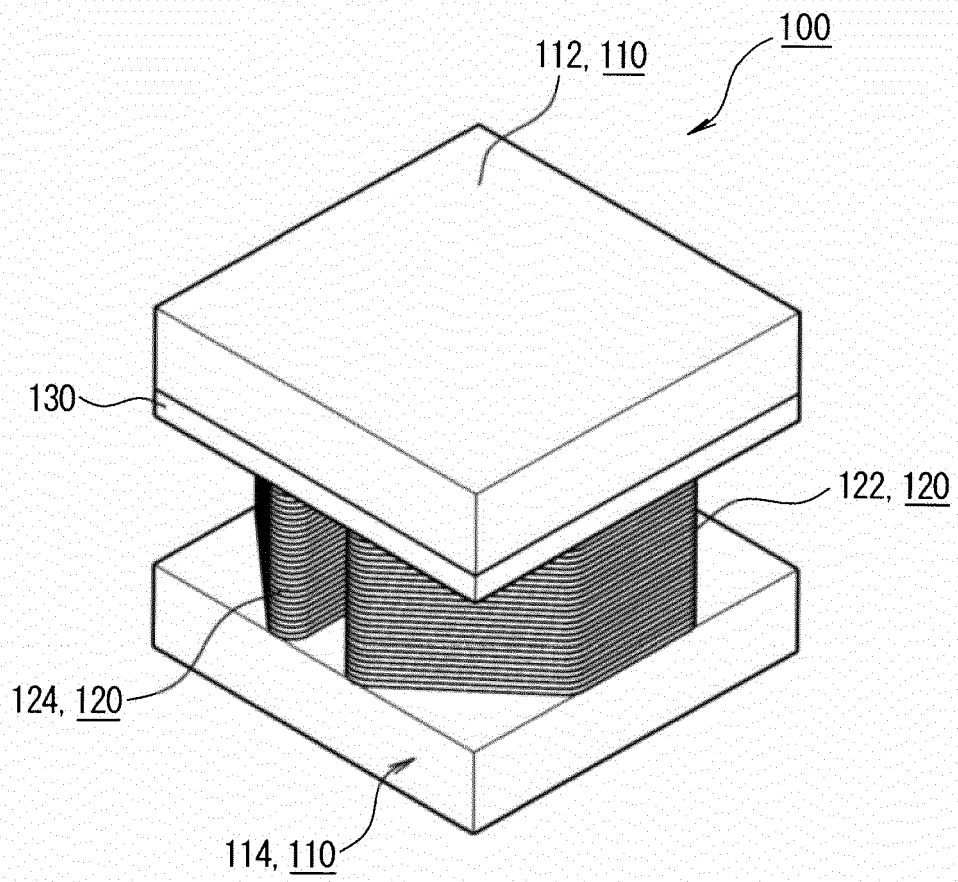


Fig. 2A

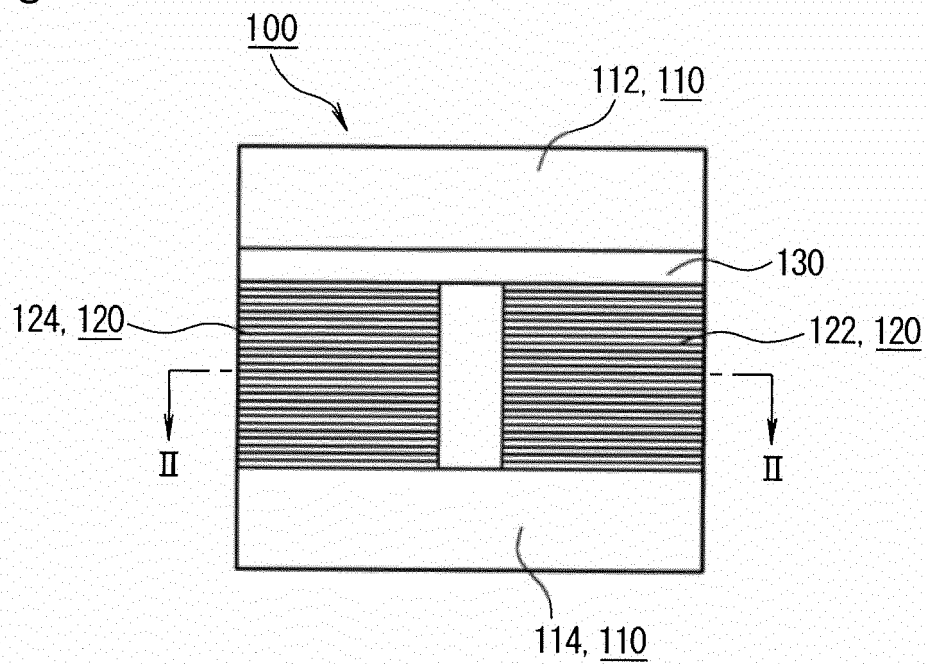


Fig. 2B

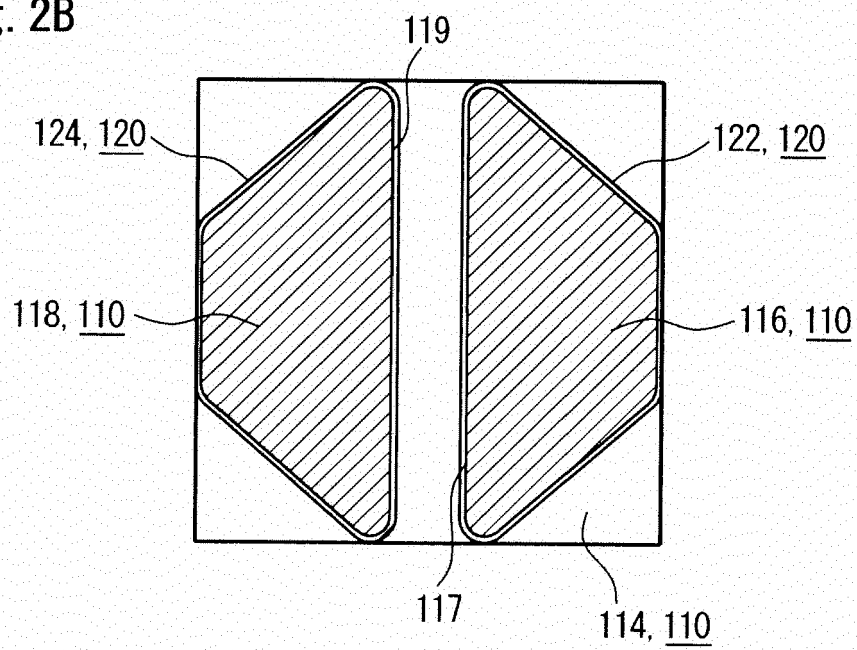


Fig. 3

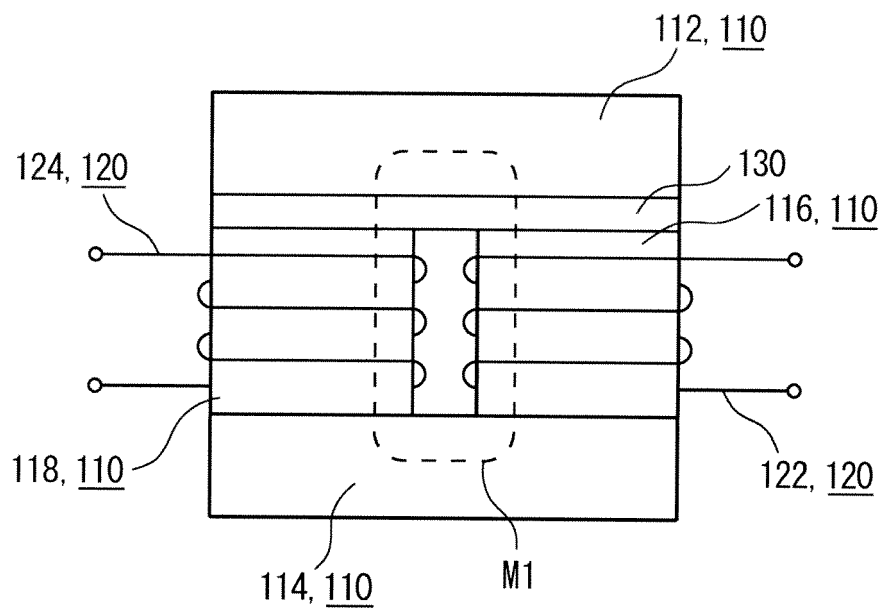


Fig. 4

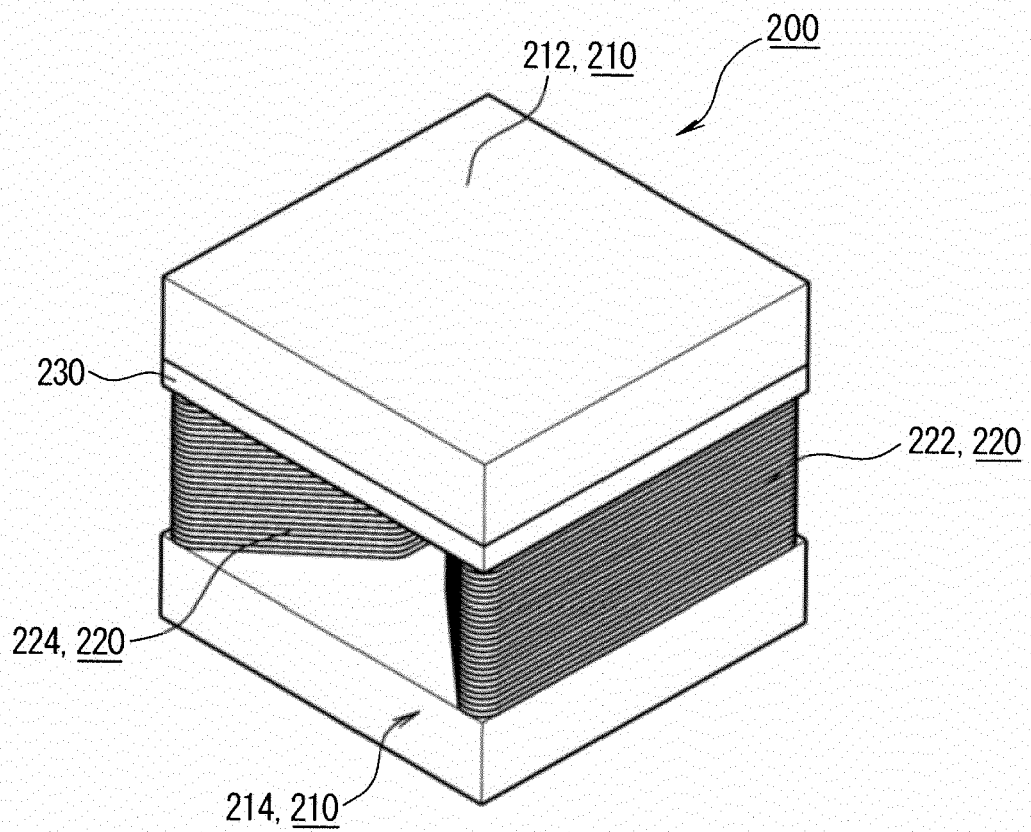


Fig. 5A

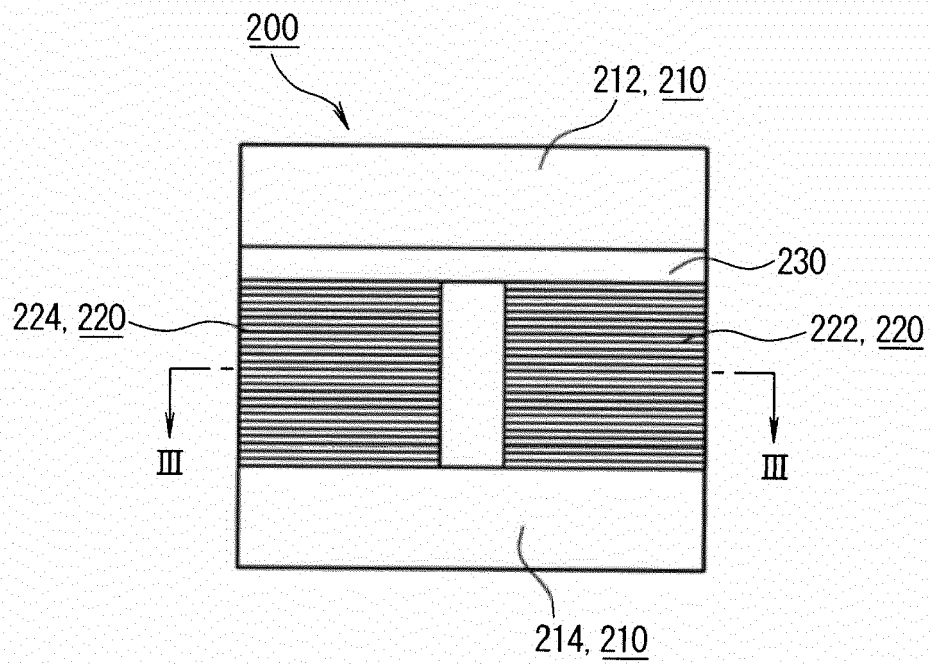


Fig. 5B

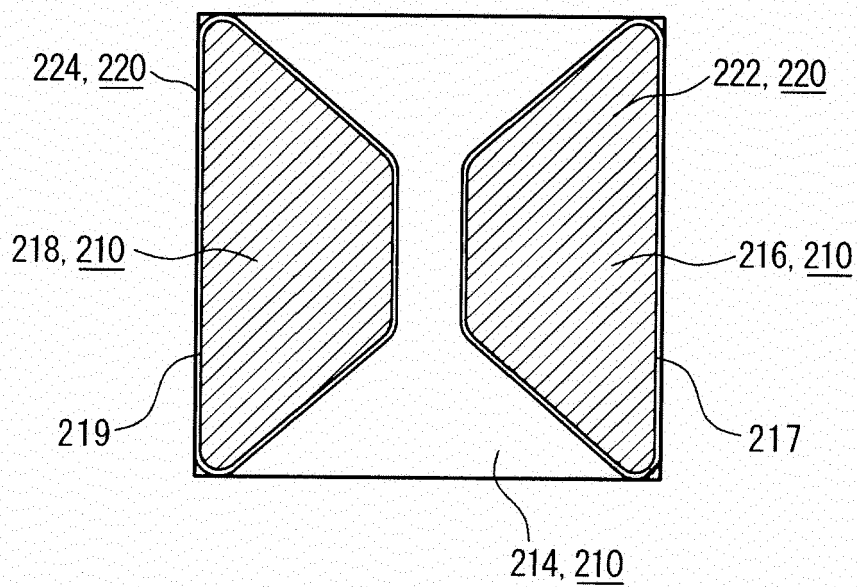


Fig. 6

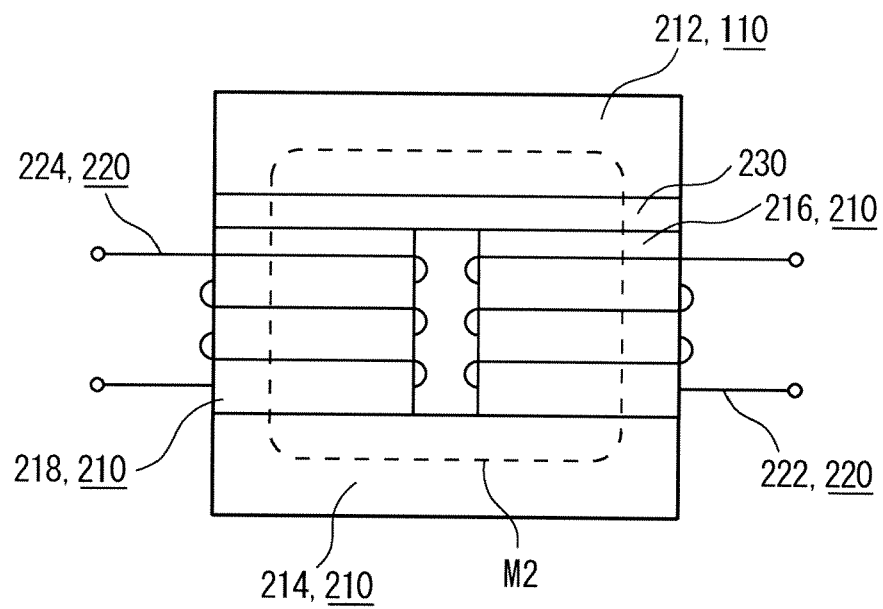


Fig. 7A

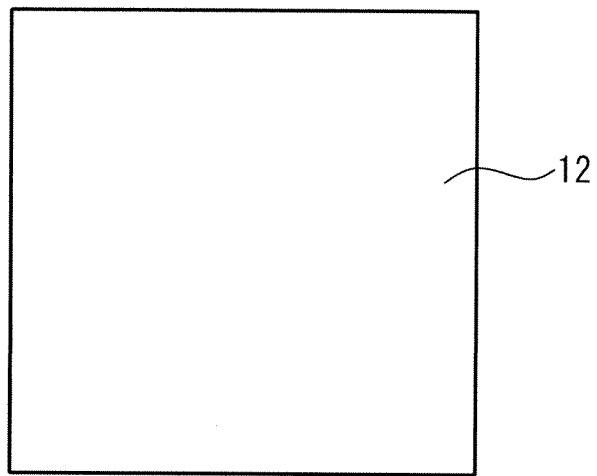


Fig. 7B

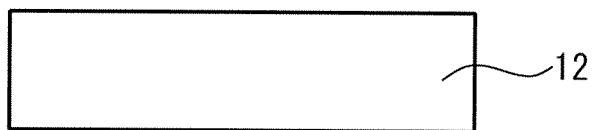


Fig. 8A

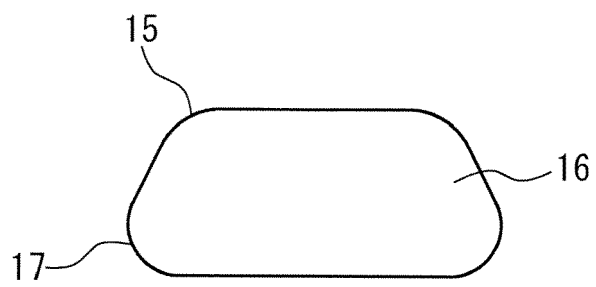


Fig. 8B

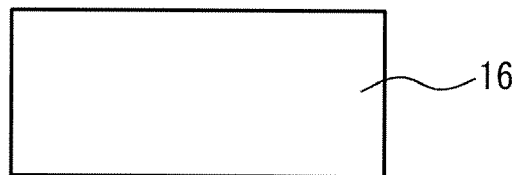


Fig. 9A

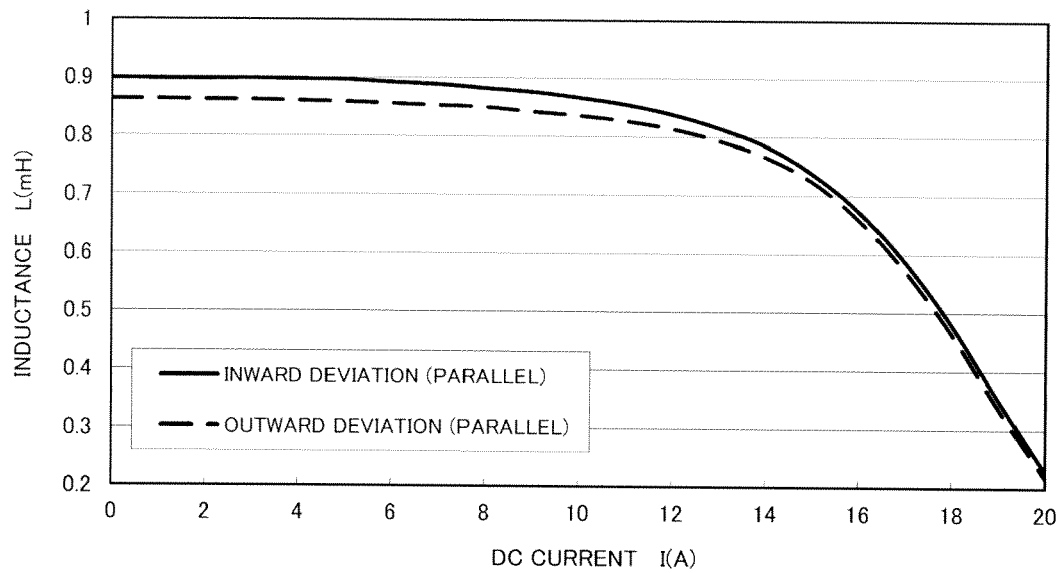


Fig. 9B

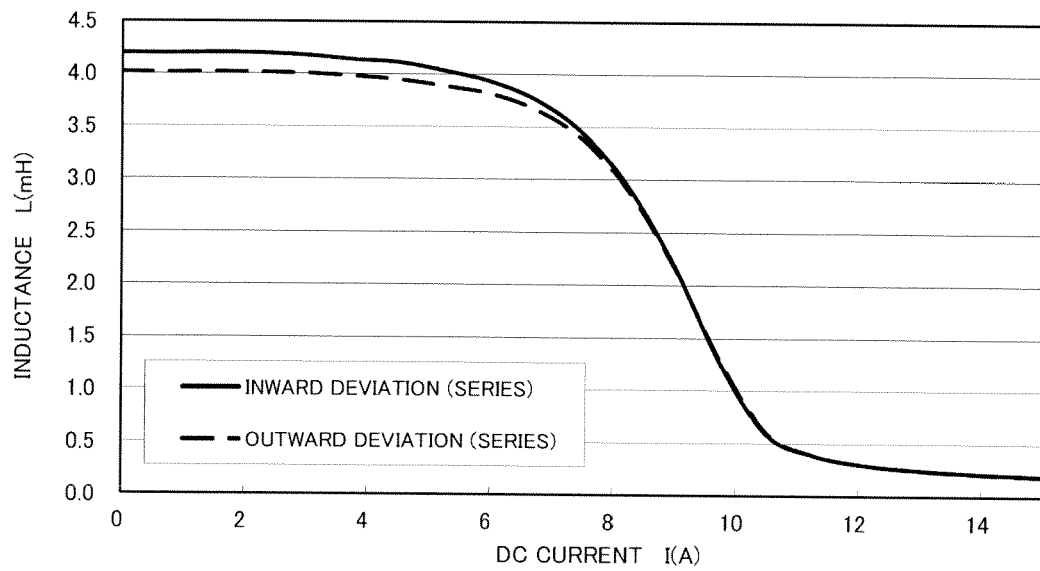


Fig. 10A

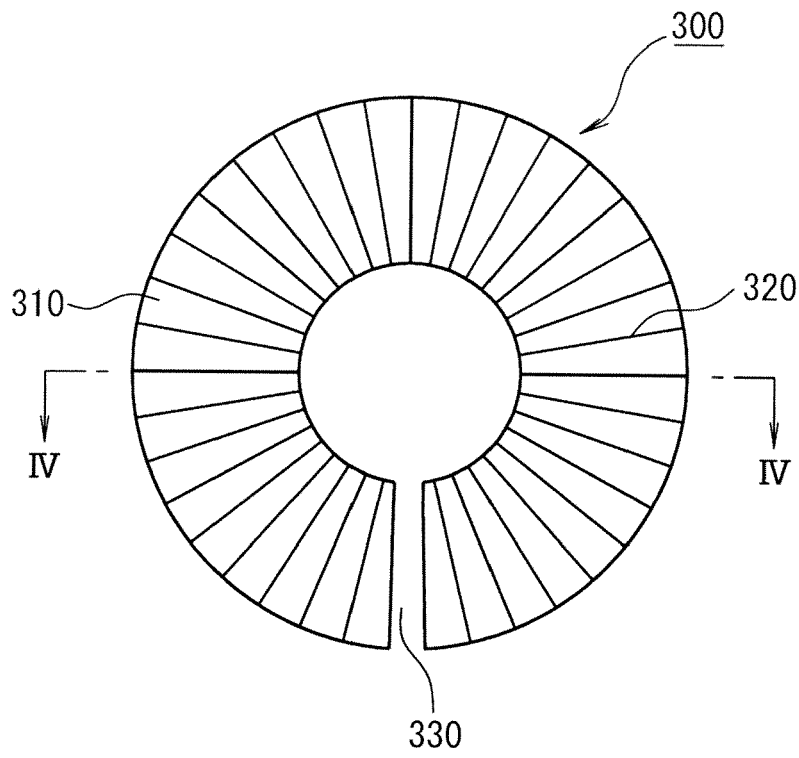


Fig. 10B

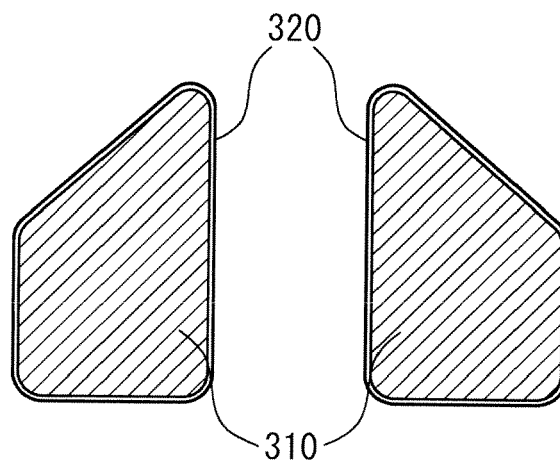


Fig. 11A

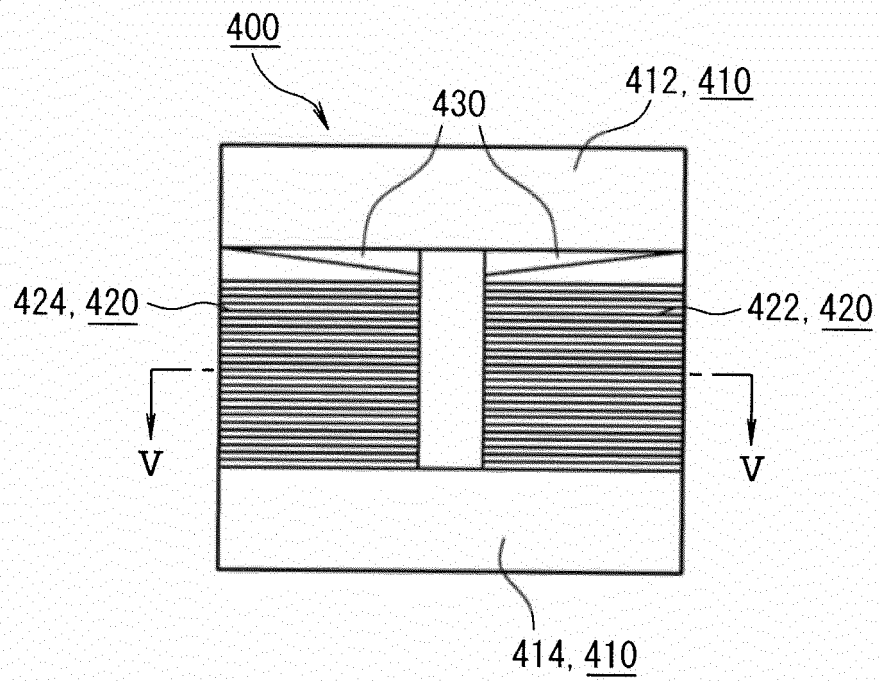


Fig. 11B

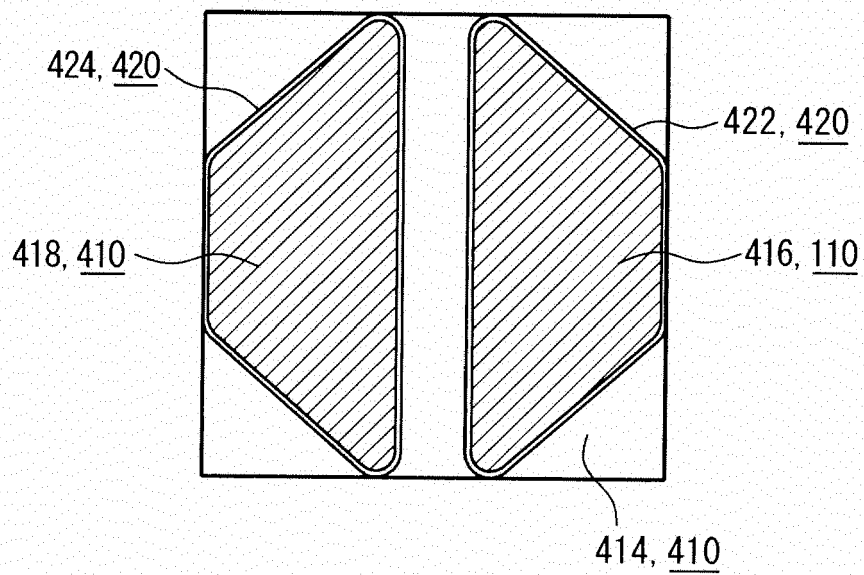


Fig. 12

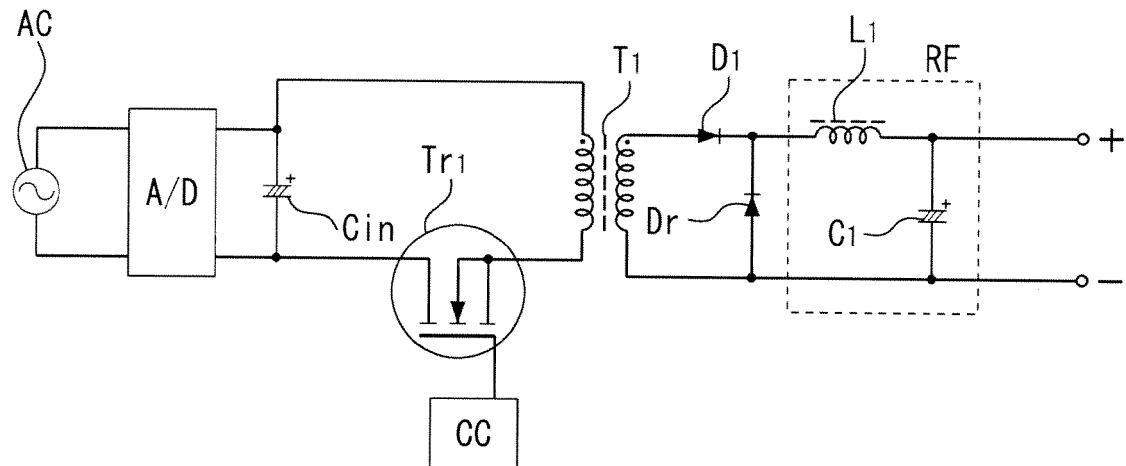
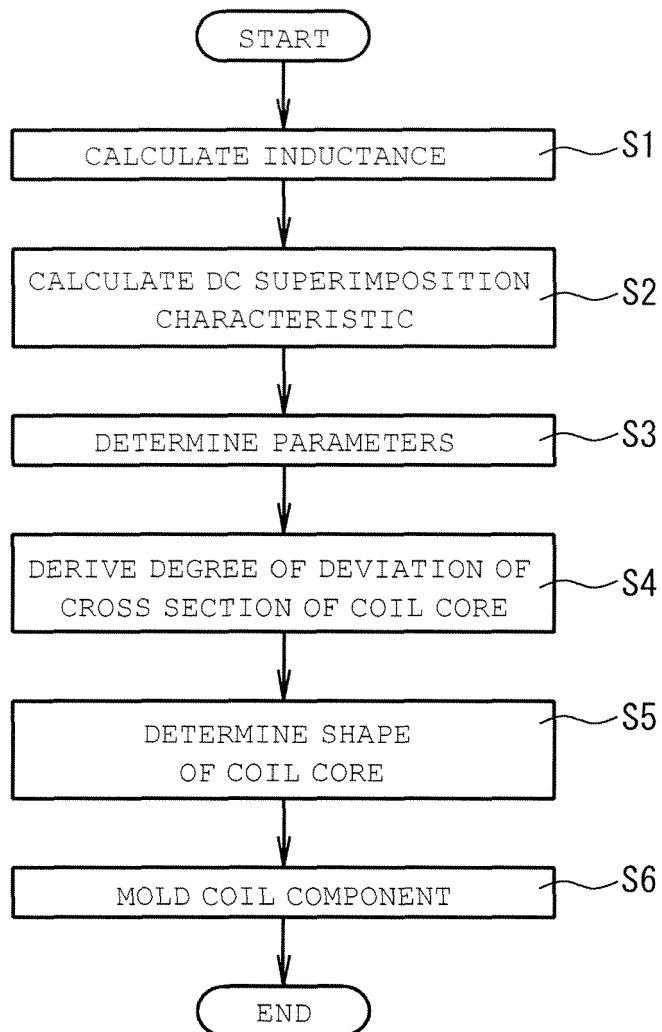


Fig. 13



REFERENCES CITED IN THE DESCRIPTION

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