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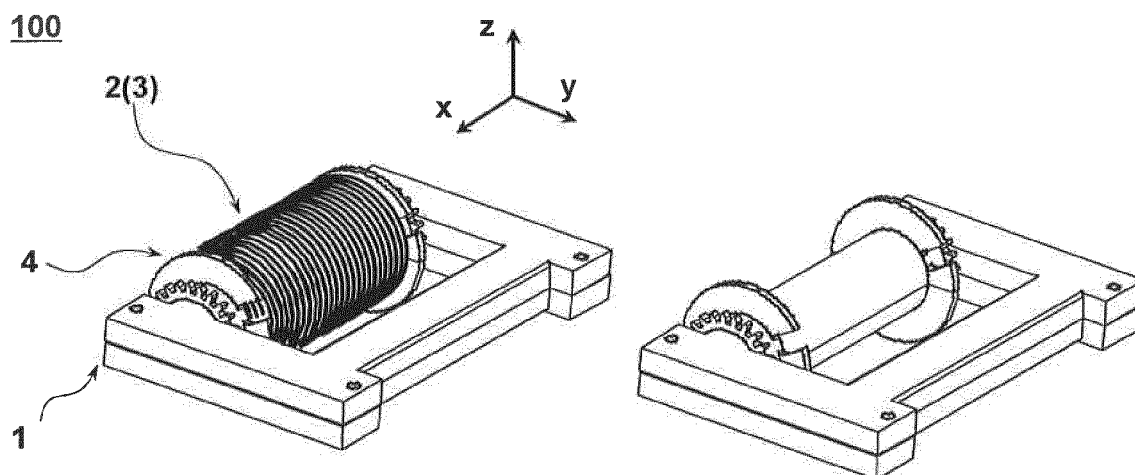
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(54) **TRANSFORMER, POWER SUPPLY DEVICE, AND METHOD FOR MANUFACTURING TRANSFORMER**

(57) A transformer (100) includes: an uncut magnetic core (5) formed by winding or layering a magnetic alloy ribbon, the uncut magnetic core forming a closed magnetic path; a protector member (1) covering the magnetic core; a primary coil (2) and a secondary coil (3); and a bobbin (4) supported rotatably around the protector member, wherein the bobbin (4) includes a cylindrical portion (7) which has a circumferential surface around

which the lead wire is to be wound, a pair of flanges (8) provided between which the circumferential surface is located, and a gear portion (9) provided on an outer side of the flanges so as to be spaced away from the flanges, and a wound portion of a lead wire which forms the primary coil and a wound portion of a lead wire which forms the secondary coil are arranged alternately in a radial direction of the cylindrical portion.

FIG. 1



Description**TECHNICAL FIELD**

5 **[0001]** The present invention relates to a transformer for use in a switched mode power supply, an insulated inverter, or the like, a manufacturing method thereof, and a power supply device.

BACKGROUND ART

10 **[0002]** A power supply device, such as a switched mode power supply or insulated inverter whose output exceeds 1 kW, is driven at about 10 kHz to 80 kHz from the viewpoint of efficiency. A typical example of the magnetic core material of a transformer for use in a switched mode power supply or the like which is driven in such a condition is a Mn-Zn ferrite. From the viewpoint of size reduction, a soft magnetic alloy material, such as an amorphous material or nanocrystalline material whose saturation magnetic flux density is high, can also be used. In a common configuration of the transformer, 15 magnetic cores molded in a "UU" or "EE" shape are joined together in a coil form formed by winding a lead wire around a bobbin beforehand, so as to form a magnetic path in a "□" shape of a Japanese Kana character, racetrack shape, or "日" shape of a Japanese Kanji Character.

[0003] In the above configuration, a gap exists at the joint surfaces even though it is very small. Particularly when using a cut core made from a soft magnetic alloy ribbon whose specific resistance is low, such a gap exists so that a loss resulting from leakage flux increases. Thus, when the soft magnetic alloy ribbon is used in the form of a cut core, the operation magnetic flux density cannot be sufficiently increased, and it is difficult to say that a design which fully exploits the properties of the soft magnetic alloy material is possible.

[0004] Meanwhile, there is a transformer which uses an uncut metallic magnetic material, such as a toroidal transformer. However, winding of a wire in the toroidal transformer is manually carried out, and therefore, a problem of poor manipulation convenience, a problem of large variations in the characteristics, etc., arise. Patent Document 1 discloses, for example, the technique of efficiently winding a wire around an uncut magnetic core, although this technique relates not to the transformer but to the line filter. In a configuration disclosed in Patent Document 1, a bobbin with a gear is attached to a "日"-shaped, closed magnetic path magnetic core, and the gear is utilized for the wire winding operation. This makes the wire winding operation easier.

CITATION LIST**PATENT LITERATURE**

35 **[0005]** Patent Document 1: Japanese Laid-Open Utility Model Publication No. 4-85714

SUMMARY OF INVENTION**TECHNICAL PROBLEM**

40 **[0006]** However, in the configuration disclosed in Patent Document 1, the primary coil and the secondary coil are arranged so as to be isolated from each other in the axial direction of the middle leg. Therefore, the coupling coefficient of the primary coil and the secondary coil decreases, and the copper loss also increases. Thus, such a configuration is not suitable for the transformer.

[0007] Thus, conventionally, it has been difficult to provide a transformer in which a characteristic of the magnetic alloy ribbon, high saturation magnetic flux density, is exploited while the manipulation convenience in the wire winding operation is secured.

50 **[0008]** In view of the above problem, an object of the present invention is to provide a small size, lightweight transformer in which high saturation magnetic flux density of the magnetic alloy ribbon is exploited while the manipulation convenience in the wire winding operation is secured, a power supply device in which the transformer is used, and a method for manufacturing the transformer.

SOLUTION TO PROBLEM

55 **[0009]** A transformer according to an embodiment of the present invention includes: an uncut magnetic core formed by winding or layering a magnetic alloy ribbon, the uncut magnetic core forming a closed magnetic path; a protector member covering at least part of the magnetic core; a primary coil and a secondary coil; and at least one bobbin around

which a lead wire which forms the primary coil and the secondary coil is to wound, wherein the at least one bobbin includes a cylindrical portion which has a circumferential surface around which the lead wire is to be wound, a pair of flanges arranged so as to sandwich the circumferential surface in an axial direction of the cylindrical portion, and at least one gear portion provided on an outer side of at least one of the pair of flanges so as to be spaced away from the flange, the at least one bobbin being supported on the cylindrical portion so as to be rotatable around the protector member, and a wound portion of a lead wire which forms the primary coil and a wound portion of a lead wire which forms the secondary coil are arranged alternately in a radial direction of the cylindrical portion.

[0010] In one embodiment, the at least one bobbin includes a plurality of bobbin members which are assembled around the protector member so as to sandwich the protector member, and each of the plurality of bobbin members includes a part of the cylindrical portion.

[0011] In one embodiment, in the at least one bobbin, lead wires of respective ones of a plurality of wound portions of a lead wire which forms the primary coil which overlaps via a wound portion of a lead wire which forms the secondary coil are connected in parallel on an outer side of the flanges, and lead wires of respective ones of a plurality of wound portions of a lead wire which forms the secondary coil which overlaps via a wound portion of a lead wire which forms the primary coil are connected in parallel on an outer side of the flanges.

[0012] In one embodiment, the at least one bobbin includes a plurality of bobbins, and the primary coil and the secondary coil are each divided into a plurality of sub-coils which are connected in parallel or in series, and the plurality of sub-coils are provided to the plurality of bobbins.

[0013] In one embodiment, the magnetic alloy ribbon has magnetic characteristics such that a saturation magnetic flux density B_s is not less than 1.0 T, and a ratio of a residual magnetic flux density B_r to the saturation magnetic flux density B_s , B_r/B_s , is not more than 0.3.

[0014] In one embodiment, an insulator in the form of a sheet is provided between a wound portion of the primary coil and a wound portion of the secondary coil.

[0015] In one embodiment, in at least one of the pair of flanges, a lead wire passage portion is provided for providing on an outer side of the flanges an end portion of a lead wire that is wound around a circumferential surface of the cylindrical portion, and the lead wire passage portion includes a recess or hole which allows passage of the lead wire at a position radially inner than an outer circumferential edge of the flanges.

[0016] In one embodiment, the lead wire passage portion includes a pair of recesses which are arranged so as to sandwich the cylindrical portion when seen in an axial direction of the cylindrical portion, and an end portion of the lead wire which forms the primary coil is provided on an outer side of the flanges via one of the pair of recesses, and an end portion of the lead wire which forms the secondary coil is provided on an outer side of the flanges via the other one of the pair of recesses.

[0017] In one embodiment, the at least one bobbin further includes a restricting section which has a surface for hindering an end portion of the lead wire provided on an outer side of the flanges via the lead wire passage portion from moving radially outward of the cylindrical portion when the bobbin is rotated.

[0018] In one embodiment, the transformer further includes a pole-like protrusion protruding radially outward of the cylindrical portion from a surface of the flanges.

[0019] In one embodiment, the protector member is a case for housing the magnetic core.

[0020] In one embodiment, the at least one bobbin has an outer circumferential surface between the flange and the gear portion, and a diameter of the outer circumferential surface is equal to a diameter of a circumferential surface of the cylindrical portion.

[0021] A power supply device according to an embodiment of the present invention is a power supply device including any of the above-described transformers.

[0022] In one embodiment, the power supply device is an insulated inverter or insulated switched mode power supply whose drive frequency is 10 to 50 kHz and output is not less than 5 kW.

[0023] A transformer manufacturing method according to an embodiment of the present invention includes: the first step of attaching a protector member to an uncut magnetic core, the uncut magnetic core being formed by winding or layering a magnetic alloy ribbon, the uncut magnetic core forming a closed magnetic path; the second step of attaching at least one bobbin, the at least one bobbin including a cylindrical portion which has a circumferential surface around which a lead wire is to be wound, a pair of flanges arranged so as to sandwich the circumferential surface in an axial direction of the cylindrical portion, and at least one gear portion which is provided on an outer side of at least one of the pair of flanges so as to be spaced away from the flange, the at least one bobbin being attached so as to be rotatable around the protector member at the cylindrical portion; and the third step of winding a lead wire around the circumferential surface of the cylindrical portion by rotating the bobbin via the gear portion, thereby forming a primary coil and a secondary coil around the cylindrical portion, wherein the third step includes the step of forming a wound portion of a lead wire which forms the primary coil and a wound portion of a lead wire which forms the secondary coil alternately in a radial direction of the cylindrical portion.

[0024] In one embodiment, the at least one bobbin includes a plurality of bobbins, and the primary coil and the secondary

coil are each divided into a plurality of sub-coils which are connected in parallel or in series, and the plurality of sub-coils are provided to the plurality of bobbins.

[0025] In one embodiment, at least one of the pair of flanges has a pair of recesses which are arranged so as to sandwich the cylindrical portion when seen in an axial direction of the cylindrical portion, and the third step includes the step of winding the lead wire which forms the primary coil while an end portion of the lead wire is provided on an outer side of the flanges from one of the pair of recesses, and the step of winding the lead wire which forms the secondary coil while an end portion of the lead wire is provided on an outer side of the flanges from the other one of the pair of recesses.

[0026] In one embodiment, in the third step, in forming a wound portion of the lead wire, an end portion of the lead wire is provided in a gap between the flange and the gear portion.

[0027] In one embodiment, the at least one bobbin further includes a restricting section which has a surface for hindering an end portion of the lead wire provided on an outer side of the flanges from moving radially outward of the cylindrical portion, and in the third step, in forming a wound portion of the lead wire, an end portion of the lead wire is provided at a position inner than the restricting section in a radial direction of the cylindrical portion.

[0028] In one embodiment, the at least one bobbin has a pole-like protrusion protruding radially outward of the cylindrical portion from a surface of the flanges, and the third step includes the step of tying an end portion of the lead wire around the protrusion.

[0029] In one embodiment, the transformer includes a case for housing a magnetic core. The case may be an assembly of an upper case and a lower case. The case may have a linear portion extending along a magnetic path of the magnetic core. The bobbin is rotatably supported on the linear portion of the case in the cylindrical portion.

[0030] In the transformer, a cross section of the magnetic core which is perpendicular to the magnetic path direction of the magnetic core has an oblong quadrangular shape. The magnetic core is housed in the case such that the long side of the oblong quadrangular cross section is on the joint portion side between the upper case and the lower case. The shape of a cross section which is perpendicular to the magnetic path direction of the magnetic core may be closer to square than the shape of the cross section of the magnetic core or may be square. Alternatively, the cross-sectional shape of the magnetic core itself may be square. The cross-sectional shape of the case in which the magnetic core is housed may also be square as well.

ADVANTAGEOUS EFFECTS OF INVENTION

[0031] According to an embodiment of the present invention, it is possible to provide a small size, lightweight transformer in which the manipulation convenience in the wire winding operation is secured, a power supply device in which the transformer is used, and a method for manufacturing the transformer.

BRIEF DESCRIPTION OF DRAWINGS

[0032]

FIG. 1 is a perspective view showing an embodiment of a transformer of the present invention.

FIGS. 2(a) and 2(b) show an exploded perspective view of a case, a magnetic core and a bobbin for use in an embodiment of the transformer of the present invention.

FIG. 3 shows a flange of a bobbin for use in an embodiment of the transformer of the present invention. FIG. 3(a) is a side view of the flange when viewed in a direction perpendicular to the axial direction the cylindrical portion.

FIGS. 3(b) and 3(c) are side views of the flange when viewed in the axial direction the cylindrical portion.

FIG. 4 is a schematic cross-sectional view showing one embodiment of the transformer of the present invention.

FIG. 5 is a schematic cross-sectional view showing another embodiment of the transformer of the present invention.

FIG. 6 is a schematic cross-sectional view showing still another embodiment of the transformer of the present invention.

FIG. 7 is a schematic cross-sectional view showing still another embodiment of the transformer of the present invention.

FIG. 8 is a graph showing the relationship between the applied magnetic flux density and the core loss.

FIG. 9(a) is a schematic cross-sectional view showing the winding state of the primary and secondary coils in a transformer of a comparative example. FIG. 9(b) is a schematic cross-sectional view showing the winding state of the primary and secondary coils in one embodiment of the transformer of the present invention. FIG. 9(c) is a diagram enlargedly showing coil portions extracted from the schematic cross-sectional view of FIG. 9(b).

FIG. 10 is a graph showing the frequency dependence of the effective resistance.

FIG. 11 is a graph showing the relationship between the temperatures of the magnetic core surface and the coil surface and the drive time.

DESCRIPTION OF EMBODIMENTS

[0033] Hereinafter, the configuration of a transformer according to an embodiment of the present invention is described.

[0034] The transformer according to an embodiment of the present invention includes an uncut magnetic core which is formed by winding or layering a magnetic alloy ribbon so as to form a closed magnetic path, a protector member covering at least part of the magnetic core, a primary coil and a secondary coil, and at least one bobbin for winding of a lead wire that is to form the primary coil and the secondary coil, the bobbin being supported rotatably around the protector member. The transformer according to an embodiment of the present invention is configured using an uncut magnetic core of a closed magnetic path in order to exploit to the fullest extent the characteristics of a magnetic alloy ribbon that has high saturation magnetic flux density.

[0035] The above-described protector member is typically a case for housing the magnetic core. The case may be, for example, an assembly including a plurality of case members which are secured to one another so as to form a space for housing the magnetic core. The case may have a linear portion extending along the magnetic path of the magnetic core. The above-described bobbin includes a cylindrical portion having a circumferential surface around which a lead wire is to be wound, a pair of flanges arranged so as to sandwich the circumferential surface in an axial direction of the cylindrical portion, and at least one gear portion which is provided on an outer side of at least one of the pair of flanges with a gap between the gear portion and the flange. In this configuration, the cylindrical portion of the bobbin is rotatably supported on the linear portion of the case.

[0036] Such a configuration enables winding of the wire by rotation via the gear portion (hereinafter, also referred to as "gear winding") and hence enables to secure the manipulation convenience in the winding of the wire with the use of an uncut magnetic core.

[0037] Further, in the transformer according to an embodiment of the present invention, a wound portion of the lead wire which forms the primary coil and a wound portion of the lead wire which forms the secondary coil are arranged alternately in a radial direction of the cylindrical portion. Thus, by employing the above-described configuration which is different from a gear-winding configuration employed in a conventional line filter such as described in Patent Document 1, coupling of the primary coil and the secondary coil is improved, and it is possible to provide a preferred configuration when applying the above-described gear winding to the transformer.

[0038] Hereinafter, a transformer and a manufacturing method thereof according to an embodiment of the present invention are specifically described with the use of the drawings, although the present invention is not limited to them. Configurations which will be described in respective embodiments can be applied to other embodiments so long as they do not mar the concepts of the other embodiments. In such a case, repetitive description will be appropriately omitted.

[0039] FIG. 1 is a perspective view showing a transformer **100** according to an embodiment of the present invention. FIG. 2 is an exploded perspective view of a case, a magnetic core and a bobbin for use in the embodiment shown in FIG. 1. The transformer **100** includes a magnetic core **5**, a case **1** as a protector member for housing and protecting the magnetic core **5**, a primary coil **2** and a secondary coil **3**, and a bobbin **4** for winding of a lead wire which is to form the primary coil **2** and the secondary coil **3**.

[0040] As described above, the magnetic core **5** is formed by winding or layering a magnetic alloy ribbon. The magnetic alloy ribbon used is, for example, a Fe-based amorphous alloy ribbon, a Co-based amorphous alloy ribbon, or a Fe-based nanocrystalline alloy ribbon, which are obtained by rapid quenching of a molten metal. Since even the Co-based amorphous alloy ribbon, which has relatively low saturation magnetic flux density, has a saturation magnetic flux density of not less than about 0.55 T, these magnetic alloy ribbons have higher saturation magnetic flux densities than ferrites and are advantageous in size reduction of the transformer. To exploit the advantage to the fullest extent, the magnetic core **5** is formed as an uncut core. Here, "uncut" means that the magnetic alloy ribbon has no disconnected portion in the middle of its magnetic path. The uncut magnetic core which forms a closed magnetic path does not cause a magnetic gap, and therefore, the effect of leakage flux is avoided, and driving of the transformer with a high operation magnetic flux density is possible.

[0041] The uncut magnetic core **5** may be a wound magnetic core which is formed by winding a magnetic alloy ribbon into an annular arrangement, or a multilayer magnetic core which is formed by layering a plurality of magnetic alloy ribbons cut into a predetermined shape. The magnetic core **5** shown in FIG. 2 is a rectangular annular magnetic core which forms a magnetic path in an oblong quadrangular shape, although the shape of the magnetic core is not limited to this example. Note that, however, the magnetic core **5** is to be housed in the case **1** that has linear portions **6** which will be described later, and therefore, using a magnetic core which has a shape which partially has a linear portion is preferred. For example, a magnetic core which has a rectangular annular shape ("□" shape), a racetrack shape, a rectangular annular shape with a middle leg ("⊞" shape), or the like, can be used. A magnetic core which has a rectangular annular or racetrack shape is also referred to as "two-legged magnetic core", and a magnetic core which has a rectangular annular shape with a middle leg is also referred to as "three-legged magnetic core". Typically, the former has two linear portions as the leg portions, and the latter has three linear portions as the leg portions.

[0042] Simple annular magnetic cores, such as rectangular annular ("□" shape) and racetrack magnetic cores, are particularly preferably manufactured in the form of a wound magnetic core from the viewpoint of productivity. Magnetic

cores which have a rectangular annular shape with a middle leg ("⊞" shape), or three-legged magnetic cores, can be formed by layering magnetic alloy ribbons cut into such a shape or by placing two wound magnetic cores side-by-side. Note that, in this specification, the term "rectangular" used herein for representing the shape of the magnetic core is not limited to a perfect rectangular shape but may include a shape that has curves (curved surface portions) at the corners which are entailed by winding of the magnetic alloy ribbon.

[0043] The composition and characteristics of the magnetic alloy ribbon that forms the magnetic core 5 are not particularly limited. Note that, however, the magnetic alloy ribbon used preferably has such magnetic characteristics that the saturation magnetic flux density B_s is not less than 1.0 T, and the ratio of the residual magnetic flux density B_r to the saturation magnetic flux density B_s , B_r/B_s , is not more than 0.3. Hereinafter, the reasons for that are described.

[0044] In an insulated switched mode power supply or the like, the transformer is configured to perform a bipolar operation for the purpose of size reduction of the transformer circuit. In the case of a bipolar operation, when the power supply is turned off, the magnetic flux density of the magnetic core of the transformer is kept in the range of $+B_r$ to $-B_r$ and does not necessarily fall on the origin of BH (asymmetric magnetization). The operation start point is $+B_r$ at the maximum. To avoid magnetic saturation, increasing the operation magnetic flux density to a level which is comparable to the saturation magnetic flux density B_s with consideration for the margin for safety in design is not a common procedure. Therefore, using a magnetic core which has lower residual magnetic flux density B_r , more precisely higher $\Delta B (=B_s - B_r)$, in other words, smaller B_r/B_s ratio, contributes more to a compact design of the transformer. Countermeasure against asymmetric magnetization include, for example, providing a gap in the magnetic core such that B_r decreases.

[0045] A magnetic metal ribbon which is made of a Fe-based amorphous material or the like has a higher saturation magnetic flux density than ferrites and is thus advantageous in size reduction of the transformer. However, if the countermeasure against asymmetric magnetization is the above-described gap, the core is cut so that the loss increases as described above, and high B_s cannot be exploited. In view of this difficulty, B_r may be decreased by carrying out a heat treatment on the magnetic metal ribbon in a magnetic field so as to cause anisotropy in a direction perpendicular to the magnetic path (i.e., so as to form an easy magnetization axis in the perpendicular direction). Causing anisotropy in a direction perpendicular to the magnetic path by means of a heat treatment in a magnetic field is advantageous because the ratio of the residual magnetic flux density B_r to the saturation magnetic flux density B_s , B_r/B_s , can be decreased. From the viewpoint of securing large ΔB , the magnetic alloy ribbon is preferably such that, as described above, the saturation magnetic flux density B_s is not less than 1.0 T, and the ratio of the residual magnetic flux density B_r to the saturation magnetic flux density B_s , B_r/B_s , is not more than 0.3. Although the upper limit of B_s is not particularly limited, B_s of a Fe amorphous material which has been put into practical use is, for example, not more than 1.8 T.

[0046] The case (protector member) 1 is an assembly consisting of two case members, an upper case 1a and a lower case 1b, which are separated vertically (z direction in the drawing). Note that the concept of the term "vertical" used herein is merely for the sake of convenience in directional expressions in assemblage. The lower case 1b has a space for housing the magnetic core 5, and the upper case 1a and the lower case 1b fit with each other such that the space is covered with the upper case 1a. In the embodiment shown in FIG. 1, the joint portion (meeting portion) between the upper case 1a and the lower case 1b is present at lateral surfaces in a direction perpendicular to the axis of the annular case 1, i.e., the xy direction. The case 1 includes a pair of linear portions 6 extending along the magnetic path of the magnetic core 5 (along the x direction in the drawing). The case 1 is a rectangular annular case which is configured according to the shape of the magnetic core 5 and also has linear portions extending in the y direction in the drawing. Note that, at the four corners of the case 1, the case 1 has portions protruding in the y direction, which serve as securing portions for fastening together the upper case 1a and the lower case 1b. Also when the case has such protruding portions or curved portions at the corners, the general shape of the case is considered as a rectangular shape.

[0047] In the magnetic core of the magnetic alloy ribbon, a cross section of the magnetic core perpendicular to the magnetic path usually has a rectangular shape no matter which form of the wound magnetic core or the multilayer magnetic core is employed. Although the contour of the cross section of the case can have a non-rectangular shape, it is preferably rectangular from the viewpoint of simplification of the case structure.

[0048] Although the contour of the cross section of a linear portion of the case which supports the cylindrical portion of the bobbin can have a circular shape or a polygonal shape which has n angles (n is a natural number not less than 5), using a case which has a rectangular cross section provides the following great advantages. When the transformer is driven, the magnetic core produces heat. Radiation of heat from a portion covered with the coil is hindered by the coil, so that the temperature of the transformer increases. On the other hand, when a case which has a rectangular cross section is used, a large space communicating with the outside of the bobbin is formed between the outer surface of the case and the inner surface of the bobbin, so that heat radiation can be enhanced, and increase in temperature of the transformer can be suppressed.

[0049] In the embodiment shown in FIG. 1, a cross section of the magnetic core 5 which is perpendicular to the

magnetic path direction has an oblong quadrangular shape. The magnetic core **5** is housed in the case **1** such that the long side of the oblong quadrangular cross section of the magnetic core **5** is on the joint portion side between the upper case **1a** and the lower case **1b**, i.e., on the inner circumferential side and the outer circumferential side of the annular case. In order to shorten the whole length of the wire wound around the bobbin, the cross-sectional shape of the case that is provided in a cylindrical portion inside the bobbin is preferably as close to square as possible. However, since in the embodiment shown in FIG. 1 the upper case **1a** and the lower case **1b** are joined together so as to partially overlap each other, the thickness of the case is relatively large in the joint portion between the upper case **1a** and the lower case **1b** as compared with the other portions when the thickness of the case is decreased for size reduction. On the other hand, a magnetic core which has an oblong quadrangular cross section is prepared and is arranged such that its long side is on the joint portion side (lateral surface side), whereby the above-described increase in thickness of the case can be offset by the difference in dimension between the long side and the short side of the magnetic core. With such a configuration provided, the shape of a cross section of the case **1** which is perpendicular to the magnetic path direction of the magnetic core **5** may be closer to square than the shape of the cross section of the magnetic core **5** (the ratio between the short side and the long side is close to 1) or may be square. Among these options, square is most preferred. In the configuration of FIG. 1, the cross-sectional shape of the case **1** is square. Note that, however, irrespective of such a form, the cross section of the above-described magnetic core may be generally square. Also in this case, by designing the case **1** so as to have a uniform thickness, the cross-sectional shape of the outer lateral surface of the case **1** can also be designed to be generally square as is the magnetic core.

[0050] The case **1** is used for the purposes of, for example, protecting the magnetic core **5** and securing insulation. So long as such purposes are accomplished, the material of the case is not particularly limited. For example, a resin such as polyethylene terephthalate (PET), polybutylene terephthalate (PBT), polyphenylene sulfide (PPS), or the like, can be used.

[0051] In the above-described configuration, the case **1** which serves as a protector member is formed by assembling a plurality of members (the upper case and the lower case), although the present invention is not limited to this example. For example, the case used may be formed by an opening-type integral member that has a housing space which conforms to the magnetic core. In this case, an insulative tape or the like may be wound around the case after the magnetic core is housed in the case such that the magnetic core would not fall out of the case. In the above-described configuration, the case **1** has a space which houses the entirety of the magnetic core **5**, although the present invention is not limited to this example. The protector member may be configured to cover only a portion of the magnetic core. Note that, however, the protector member is preferably arranged so as to cover at least part of the magnetic core to which the bobbin is to be attached. Due to this arrangement, as will be described later, when the bobbin is rotated around the magnetic core, the probability of damaging the magnetic core by the intervening protector member can be reduced. When the strength is insufficient only with the protector member, the strength of the magnetic core itself can be improved by means of resin impregnation.

[0052] Although various forms can be thus employed as the protector member, using the case enables protection of the magnetic core through a relatively convenient process and smooth rotation of the bobbin while a portion to which the bobbin is to be attached is surely protected.

[0053] The bobbin **4** includes a cylindrical portion **7** that has a circumferential surface around which a lead wire is wound, and a pair of flanges **8** that are provided at the opposite ends of the cylindrical portion **7** such that the circumferential surface of the cylindrical portion **7** is located therebetween in the axial direction. The flanges **8** are in the form of a circular plate whose outside diameter is greater than the outside diameter of the cylindrical portion **7**, and define a winding portion for a lead wire. The bobbin **4** further includes gear portions **9** for receiving the torque. The gear portions **9** are provided on the outer side of the flanges **8** (on the opposite side to the winding portion for the lead wire when viewed in the x direction in the drawing) with a gap between the gear portions **9** and the flanges **8**. That is, the gear portions **9** are spaced away from the neighboring flanges **8** in the axial direction of the cylindrical portion **7** (x direction). In the embodiment shown in FIG. 1, the gear portions **9** are provided at the top ends of the cylindrical portion **7**. Between the flanges **8** and the gear portions **9**, there are circumferential surfaces (also referred to as "outer circumferential surfaces") which have the same diameter as that of the circumferential surface of the cylindrical portion **7**.

[0054] The bobbin **4** is also formed by an assembly of two separate portions (also referred to as "bobbin members") **4a**, **4b** as is the above-described case **1**. The two separate portions **4a**, **4b** are assembled so as to bind the case **1**, and the joint portion is formed along the axial direction of the cylindrical portion. The separate portions **4a**, **4b** may be secured to each other. In this configuration, the separate portions **4a**, **4b** respectively have half cylinder portions which form the cylindrical portion **7**. The separate portions **4a**, **4b** are assembled such that the respective half cylinder portions bind the case **1**, whereby a bobbin is obtained which is rotatable around the case **1**. Note that the bobbin **4** may consist of three or more bobbin members which are positioned around the case **1** so as to surround the case **1**, although the bobbin **4** preferably consists of two bobbin members from the viewpoints of the number of parts and securing of the strength.

[0055] The inner circumferential surface of the cylindrical portion **7** of the bobbin **4** and the corners of the case **1** are arranged so as to be in moderate contact with each other, or so as to have slight clearance therebetween. The bobbin

4 is rotatably supported on the linear portions **6** of the case **1** at the cylindrical portion **7**. The gear portions **9** are coaxial with the cylindrical portion **7**, and the cylindrical portion **7** rotates integrally with the gear portions **9**. Therefore, winding of the wire is realized by transmitting the driving force of a motor, or the like, to the gear portions **9**, and the manipulation convenience in the wire winding operation is secured. Although in the embodiment shown in FIG. **1** the gear portion is provided at opposite ends of the cylindrical portion **7**, the gear portion can be provided at only one end. Note that, however, from the viewpoint of stable rotation of the bobbin **4**, the gear portion is preferably provided at each of the opposite ends of the cylindrical portion.

[0056] In the embodiment shown in FIG. **1**, the flanges **8** that are provided at opposite ends of the cylindrical portion **7** have recesses **10** at opposite ends separated from each other by the hollow portion of the cylindrical portion **7** when viewed in the axial direction of the cylindrical portion **7** (x direction). The recesses **10** are typically provided at positions symmetrical about the center axis of the cylindrical portion **7** (or at positions in the ring-shaped flanges **8** which are different by 180° in the circumferential direction). In this configuration, the wound-wire terminal (lead) of the primary coil **2** is drawn out from one of the recesses **10** at the opposite ends, and the wound-wire terminal (lead) of the secondary coil **3** is drawn out from the other one of the recesses **10**. Note that, in the embodiment shown in FIG. **1**, two recesses **10** are provided in each flange **8**, i.e., four recesses **10** are provided in total, although one of the recesses **10** at the opposite ends separated from each other by the opening of the cylindrical portion **7** is not illustrated because it is present behind the bobbin. In each coil, both of its wound-wire terminals are drawn out from the recesses formed in respective different flanges, although each wound-wire terminal (lead) is omitted from the drawing for the sake of convenience. The positions at which the wound-wire terminals of the primary coil and the secondary coil are drawn out are separated from each other by 180° around the axis of the cylindrical portion **7**, whereby insulation between the primary coil and the secondary coil in a wound-wire terminal process is improved.

[0057] The flanges are not limited to the above-described recesses. The flanges may have holes from which the wound-wire terminals of the respective coils are drawn out to the outer side of the flanges. Note that, however, the configuration where the wound-wire terminals are drawn out from the recesses is preferred because it achieves higher manipulation convenience in the wire winding operation.

[0058] Note that, in this specification, the above-described recesses and holes are sometimes generically referred to as "lead wire passage portions". Through the lead wire passage portions that are thus provided in the flanges, the ends of the lead wires are drawn out to the outer side of the flanges. The lead wire passage portions are designed such that the lead wires can pass through positions which are radially inner than the outer circumferential edges of the flanges.

[0059] By providing the lead wire passage portions (e.g., recesses) as described above, the wound-wire terminal of each coil can be directly drawn out in the axial direction without being unnecessarily routed around in a radial direction of the cylindrical portion **7**. From this viewpoint, it is preferred that the recesses **10** start from the outer circumferential edge of the flanges **8** and reach the outer circumferential surface of the cylindrical portion **7** as in the embodiments shown in FIG. **1** and FIG. **2**. Although the shape of the recesses **10** is not particularly limited, the recesses **10** may be formed in the shape of, for example, a slit which has a sufficient width for drawing out the lead wire.

[0060] Although in the embodiment shown in FIG. **1** one pair of the recesses **10** is provided in each of the flanges, providing two pairs of the recesses **10** according to the configuration of the coil is also possible. However, from the viewpoint of securing the space between the drawn-out wound-wire terminals, it is preferred that one flange has only one pair of recesses.

[0061] Although the recesses **10** are provided in the flanges **8** at opposite ends of the cylindrical portion **7**, only one of the flanges **8** at opposite ends of the cylindrical portion **7** can have recesses, such that the wound-wire terminal at the starting end of winding of one coil and the wound-wire terminal at the finishing end of winding of the coil are drawn out from one of the flanges. Note that, however, from the viewpoint of securing insulation, it is preferred that concentrated distribution of recesses in one of the flanges is avoided, and the recesses **10** are dispersedly provided in both the flanges **8** at opposite ends as in the embodiment of FIG. **1**.

[0062] The bobbin preferably has a structure which is capable of restricting movement of the wound-wire terminals of respective coils which are provided on (drawn out to) the outer side of the flanges as described above such that the wound-wire terminals would not disassemble during the wire winding operation. Note that the wound-wire terminal of a coil which is provided on the outer side of the flange may refer to an end portion which is drawn out from the cylindrical portion to the outer side of the flange as the starting end of winding of the coil, or may refer to an end portion at the starting end or finishing end of a previously-wound coil. In this specification, an end portion of a wound wire which is provided on the outer side of the flange at the start of winding is sometimes represented as an end portion "drawn out" to the outer side of the flange.

[0063] FIG. **3** shows an exemplary embodiment of the above-described restriction structure. FIG. **3(a)** shows one end side of the cylindrical portion **7** which is viewed in a direction perpendicular to the axial direction of the cylindrical portion **7** (x direction), i.e., y direction. FIG. **3(b)** shows a bobbin viewed in the axial direction of the cylindrical portion **7** (x direction), in which only flanges are illustrated while illustration of gear portions is omitted for the sake of convenience. In the embodiment shown in FIGS. **3(a)** and **3(b)**, pole-like protrusions **11** are provided extending outward in the axial

direction of the cylindrical portion 7 (x direction) from the surface of the flange 8.

[0064] The pole-like protrusions 11 are utilized for restricting the wound-wire terminals (lead wire end portions) of the respective coils from moving outward in a radial direction during gear winding. For example, the wound-wire terminals drawn out from the recesses 10 are routed along the outer circumferential surface which has the same diameter as the cylinder circumferential surface in a space between the flanges 8 and the gear portions 9. In this process, the wound-wire terminals are routed so as to be provided radially inner than the protrusions 11, i.e., provided at radial positions between the circumferential surface of the cylindrical portion 7 (or the above-described outer circumferential surface) and the pole-like protrusions 11, such that the protrusions 11 can function as retaining members for hindering the wound-wire terminals from moving outward in a radial direction. For example, in the configuration illustrated in FIGS. 3(a) to 3(c), a lead wire end portion drawn out from a recess 10 on one side is routed by the length of a half circumference along the outer circumferential surface to the protrusion 11 in the vicinity of the other recess such that, even if the wound-wire terminal of the coil moves outward in a radial direction during gear winding, the lateral surface of the protrusion 11 (a surface on the cylinder axis center side) comes into contact and thus can hinder further movement of the wound-wire terminal of the coil.

[0065] Also, such a configuration is possible where a wound-wire terminal drawn to the outer side of the flange 8 from the recess 10 is routed through a space between the flange 8 and the gear portion 9 (a space over the outer circumferential surface) and tied to the protrusion 11 (looped around the protrusion 11). The height of the protrusion 11 from the surface of the flange 8 is set within a range which does not overlap the gear portion 9. This prevents the protrusions 11 from obstructing the wire winding operation.

[0066] Note that the restriction structure is not limited to the protrusions 11. A restricting section of any other form may be provided in a space between the flange and the gear portion of the bobbin. The restricting section only needs to have a surface which hinders a lead wire end portion extending to the outer side of the flange from moving outward in a radial direction when the bobbin is rotated. For example, it may be a plate-like portion extending with a width along the circumference of the flange. The restricting section is not limited to an element protruding from the flange, but may be an element protruding from the gear portion.

[0067] Note that, in the embodiment shown in FIGS. 3(a) and 3(b), the radial position of the protrusion 11 is a position separated toward the center from the outer edge of the flange 8. Note that, however, the radial position of the protrusion 11 is not limited to such a position. As shown in FIG. 3(c), a protrusion 11' can be provided at a radially terminal end (outer edge) of the flange 8. This configuration has such advantages that a large space can be secured for housing the wound-wire terminal, and routing of the wound-wire terminal is easy.

[0068] As described above, in some cases, the wound-wire terminal drawn out from the recess of the flange had better have a certain amount of length for securing easiness in a wound-wire terminal process, such as terminal connection after the wire winding operation. In this case, a circumferential position at which the protrusion 11 is to be provided is not at a recess from which a wound-wire terminal to be restricted by this protrusions 11 from moving is to be drawn out, but may be a position near the other recess. In the embodiment shown in FIG. 3, the recess 10 and the protrusion 11 are provided at opposite ends which are separated from each other by 130° or more in the circumferential direction of a half part 8a (8b) of the flange. Arrangement of the above-described recesses and protrusions only need to be realized when the half parts are combined together, and therefore, the recesses and protrusions can be provided near the center in the circumferential direction of each half part. Note that, however, formation of a bobbin with protrusions is easy when the protrusions 11 are positioned at the terminal ends in the circumferential direction of the half part 8a (8b) as in the embodiment shown in FIG. 3.

[0069] Although the material of the bobbin 4 is not particularly limited, a resin such as polyethylene terephthalate (PET), polybutylene terephthalate (PBT), polyphenylene sulfide (PPS), or the like, can be used as is the case with the case 1.

[0070] Next, a configuration example of the coil which is applied to the embodiment of FIG. 1 is described. FIG. 4 is a schematic cross-sectional view showing one embodiment of the transformer. Wound portions **Np** of a lead wire which forms the primary coil 2 and wound portions **Ns** of a lead wire which forms the secondary coil 3 are arranged alternately in a radial direction of the cylindrical portion 7 (in FIG. 4, y direction). The plurality of wound portions **Np** that form the primary coil 2 are connected in parallel with one another. The plurality of wound portions **Ns** that form the secondary coil 3 are also connected in parallel with one another. The wound portions **Np** of the primary coil and the wound portions **Ns** of the secondary coil are provided at the same portions of the magnetic core 5 such that coils are formed with the lead wire of the primary coil and the lead wire of the secondary coil being in close contact with each other, and therefore, coupling between the coils is improved. Realizing a transformer of a high coupling coefficient can suppress increase of the effective resistance (AC resistance). That is, as shown in FIG. 4, according to a configuration where the wound portions of the primary coil and the wound portions of the secondary coil are arranged alternately in a radial direction of the cylindrical portion, the effect of suppressing increase of the copper loss is obtained. Together with the effect of reducing the gap loss which is achieved by the use of the above-described uncut magnetic core, this configuration contributes to loss reduction and size reduction in the transformer.

[0071] In the wound portions **Np** and **Ns**, the lead wire is wound around the cylindrical portion **7** from one end to the other end of the cylindrical portion **7** (x direction). Although in the wound portions the lead wire can be wound in a radially-layered arrangement, it is preferred from the purpose of improving the above-described coupling between the coils that each wound portion has a single layer arrangement, without layering of the lead wire.

[0072] As a configuration of the wound wire, in alternately arranging the wound portions **Np** and **Ns** in a radial direction of the cylindrical portion **7**, respectively providing the wound portions **Np** and **Ns** in a one-by-one manner to form the primary coil **2** and the secondary coil **3** is possible. However, it is advantageous that, as in the embodiment shown in FIG. **4**, the primary coil **2** and the secondary coil **3** are each divided into a plurality of wound portions which are connected in parallel, and the plurality of wound portions are arranged alternately in a radial direction of the cylindrical portion in each of the primary coil and the secondary coil. Such a configuration reduces the resistance of the coils and improves the coupling of the primary coil **2** and the secondary coil **3**. The form of connection of the divided coils is not limited to parallel connection, but serial connection is applicable. Dividing and alternately arranging the lead wire as described above is more advantageous in terms of the coupling between the coils than winding the lead wire into a layered arrangement.

[0073] The above-described coil configuration is also applicable to a transformer which uses a magnetic core which has a rectangular annular shape with a middle leg ("⊞" shape). FIG. **5** is a schematic cross-sectional view showing an embodiment of such a transformer. This is different from the embodiment shown in FIG. **4** in that a bobbin **14** which has a primary coil **12** and a secondary coil **13** is provided at the middle leg of a magnetic core **15**. However, the configurations of the coils and the bobbin are the same as those of the embodiment shown in FIG. **4**, and descriptions thereof are herein omitted.

[0074] Note that the magnetic core which has the configuration shown in FIG. **5** may be configured such that, for example, two annular magnetic cores obtained by winding or layering a magnetic alloy ribbon are arranged side-by-side in a case, and a neighboring portion is used as a middle leg.

[0075] Next, another embodiment which has a different coil configuration from that of the embodiment of FIG. **1** is described. In a transformer shown in FIG. **6**, a primary coil **16** is divided into two sub-coils **16a**, **16b** which are connected in series, and a secondary coil **17** is divided into two sub-coils **17a**, **17b** which are connected in series. The transformer shown in FIG. **6** includes a plurality of bobbins **18**, **19** which are rotatably provided to a magnetic core **20**. One of the divided sub-coils (sub-coil **16a** and sub-coil **17a**) is wound around one of the bobbins (bobbin **18**), and the other sub-coil (sub-coil **16b** and sub-coil **17b**) is wound around the other bobbin (bobbin **19**). The bobbins **18**, **19** are respectively provided at a pair of opposing linear portions of the magnetic core **20** that has a rectangular annular shape ("⊞" shape).

[0076] In each of the bobbins, the primary coil (sub-coils) and the secondary coil (sub-coils) are each divided into a plurality of wound portions which are connected in parallel, and the plurality of wound portions are arranged alternately in a radial direction of the cylindrical portion in each of the primary coil and the secondary coil. This configuration is the same as that shown in FIG. **1**. The configuration shown in FIG. **6** is a configuration where, in each of the primary coil and the secondary coil, the sub-coils provided to the bobbin **18** and the sub-coils provided to the bobbin **19** are connected in series such that the number of coil windings can be increased.

[0077] Next, still another embodiment which has a different coil configuration from that of the embodiment of FIG. **1** is described. In a transformer shown in FIG. **7**, a primary coil **21** is divided into two sub-coils **21a**, **21b** which are connected in parallel, and a secondary coil **22** is divided into two sub-coils **22a**, **22b** which are connected in parallel. The transformer shown in FIG. **7** includes a plurality of bobbins **23**, **24** which are rotatably provided to a magnetic core **25**. One of the divided sub-coils (sub-coil **21a** and sub-coil **22a**) is wound around one of the bobbins (bobbin **23**), and the other sub-coil (sub-coil **21b** and sub-coil **22b**) is wound around the other bobbin (bobbin **24**). The bobbins **23**, **24** are respectively provided at opposing two side portions of the magnetic core **25** that has a rectangular annular shape ("⊞" shape).

[0078] In each of the bobbins, the primary coil (sub-coils) and the secondary coil (sub-coils) are each divided into a plurality of wound portions which are connected in parallel, and the plurality of wound portions are arranged alternately in a radial direction of the cylindrical portion in each of the primary coil and the secondary coil. This configuration is the same as that shown in FIG. **1**. The configuration shown in FIG. **7** is a configuration where, in each of the primary coil and the secondary coil, the sub-coils provided to the bobbin **23** and the sub-coils provided to the bobbin **24** are connected in parallel such that the resistance of the coils can be reduced.

[0079] The configuration where each of the primary coil and the secondary coil are divided into a plurality of sub-coils which are connected in parallel or in series is not limited to the above-described embodiments. The primary coil and the secondary coil only need to include divided portions which are connected in parallel or in series.

[0080] It is also possible to use an electric wire with insulating coating, such as a three-layer insulated electric wire, as the lead wire that forms the primary coil and the lead wire that forms the secondary coil, such that the insulating coating secures insulation between the primary coil and the secondary coil. Note that, however, when a high withstand voltage is required, securing insulation between the primary coil and the secondary coil by means of insulating coating over every lead wire leads to increase in volume of the entire wound portions. Therefore, using a common magnet wire

(enameled wire), or the like, to provide a sheet-like insulator between the wound portion of the primary coil and the wound portion of the secondary coil is preferred. Using a sheet-like insulator which has not only a desired withstand voltage but also flexibility and strength such that it can be wound around the bobbin also enables winding of a sheet-like insulator with the utilization of rotation of the above-described gear portions. Preferred examples of the sheet-like insulator include a resin sheet of polyester, polyimide, polyphenylene sulfide, or the like, and non-woven insulating paper of aramid fiber or the like (e.g., NOMEX (NOMEX is a registered trademark of Du Pont)). In consideration of insulation and flexibility, the thickness is 25 to 50 μm in the case of a resin sheet of polyester or the like, and desirably 50 to 200 μm in the case of non-woven insulating paper. The number of windings of a sheet-like insulator is not particularly limited, but preferably two or more from the viewpoint of insulation and reliability. On the other hand, if the number of windings is larger than required, the number of steps includes. Thus, it is preferred that the number of windings is not more than 10.

[0081] Next, a method for manufacturing a transformer according to an embodiment of the present invention is described. Specific description of portions overlapping the previous description of the transformer is omitted. The method includes: the first step of attaching a protector member to an uncut magnetic core, the uncut magnetic core being formed by winding or layering a magnetic alloy ribbon and forming a closed magnetic path (including a configuration where the uncut magnetic core is housed in a case); the second step of attaching at least one bobbin, the at least one bobbin including a cylindrical portion which has a circumferential surface around which a lead wire is to be wound, a pair of flanges which are typically provided at opposite ends of the cylindrical portion such that the pair of flanges are separated from each other by the circumferential surface in an axial direction of the cylindrical portion, and at least one gear portion which is provided on the outer side of at least one of the pair of flanges so as to be spaced away from the flange, the at least one bobbin being attached so as to be rotatable around the protector member such that the cylindrical portion covers the protector member; and the third step of winding a lead wire around the circumferential surface of the cylindrical portion by rotating the bobbin via the gear portion, thereby forming a primary coil and a secondary coil around the cylindrical portion. The third step includes the step of alternately forming a wound portion of a lead wire which forms the primary coil and a wound portion of a lead wire which forms the secondary coil in a radial direction of the cylindrical portion. Note that the aforementioned protector member may be a case which has a linear portion and is configured to house the magnetic core. The bobbin may be rotatably attached to the linear portion of the case.

[0082] When the gear portions are rotated for carrying out winding, the wire winding operation is easy even if the uncut magnetic core is used. Further, wound portions of the lead wire that forms the primary coil and wound portions of the lead wire that forms the secondary coil can be alternately formed with high accuracy in a radial direction of the cylindrical portion.

[0083] Preferred forms, such as a configuration where each of the primary coil and the secondary coil are divided into a plurality of sub-coils which are connected in parallel or in series, a configuration featuring recesses in the flanges, and a configuration featuring protrusions protruding from the surface of the flanges, are as described above. Among these configurations, the configuration featuring protrusions is further described below.

[0084] In the third step described above, a pole-like protrusion protruding from the surface of the flange may be used as a restriction structure for restricting radially outward movement of a wound-wire terminal during winding of a lead wire (during rotation of the bobbin). For example, a wound-wire terminal drawn out from the recess **10** is routed through a space over the outer circumferential surface between the flange **8** and the gear portion **9**. If herein the wound-wire terminal is routed so as to be provided between the cylindrical portion **7** and the pole-like protrusion **11**, the protrusion **11** functions as a retaining member for retaining the wound-wire terminal. Only routing the wound-wire terminal so as to be provided between the protrusion and the cylindrical portion can confine the wound-wire terminal. In each wound portion, the wound-wire terminal may be tied to the protrusion such that the wound-wire terminal is more securely confined. In each wound portion, the wound-wire terminal is temporarily confined by the protrusion or tied to the protrusion, and after formation of all wound portions is finished, a process such as connection of the wound-wire terminal is carried out. In this case, the wound-wire terminal would not disassemble, and the wire winding operation is easy.

[0085] A transformer according to an embodiment of the present invention can effectively exploit the characteristics of a magnetic alloy ribbon which has high magnetic flux density while securing the manipulation convenience in a wire winding operation, and is thus applicable to various power supply devices. For example, it is suitable to a power supply device, such as a switched mode power supply or insulated inverter whose output exceeds 1 kW. Particularly when a transformer according to the present invention is used as a built-in insulated transformer for a power supply device whose driving frequency is 10 to 50 kHz and output is not less than 5 kW, for example, a power conditioner for alternative energy, such as solar power generation, wind power generation, a power storage unit, or the like, an insulated transformer for an auxiliary power supply device of electric trains, or a step-down transformer of an arc welder, it contributes to size reduction and weight reduction of the insulated transformer and devices and to improvement in the versatility of the entire system.

[Examples]

[0086] FIG. 8 shows the dependence of the core loss on the maximum applied magnetic flux density B_m in a cut core and an uncut core of a Fe-based nanocrystalline alloy ribbon that is a magnetic alloy ribbon at the frequencies of 10 kHz, 20 kHz, and 50 kHz. The cut core used was F3CC 6.3 manufactured by Hitachi Metals, Ltd. The cut cores were joined such that no gap was deliberately formed, whereby a magnetic core was formed. The uncut magnetic core used was formed using a FT-3L material (B_s : 1.23 T, B_r/B_s : 0.05) manufactured by Hitachi Metals, Ltd. The cut core (F3CC 6.3) and the uncut core were respectively provided with three turns of primary wiring and three turns of secondary wiring, and connected to a BH analyzer (SY8232 manufactured by IWATSU) via an amplifier (4025 manufactured by NF CORPORATION) for measurement of the core loss.

[0087] As seen from FIG. 8, comparing at the same B_m and frequency, the core loss of the uncut core is not more than 40% of that of the cut core. Converting to the operation magnetic flux density in which a magnetic flux density which produces a certain amount of core loss is allowable, this means that the uncut core can allow an operation magnetic flux density which is about 1.6 times that of a cut core which is made of the same core material.

[0088] Next, the effective resistance (AC resistance) of a transformer which has a configuration such as shown in FIG. 1 was compared between a case where a primary coil 27 and a secondary coil 28 were wound around a bobbin 26 with the primary coil 27 and the secondary coil 28 being separated in the magnetic path direction as shown in FIG. 9(a) (coil A: comparative example) and a case where a primary coil 31 and a secondary coil 32 were wound around a bobbin 30 alternately in a radial direction as shown in FIG. 9(b) (coil B: example). The magnetic cores 29, 33 are uncut wound magnetic cores in which the aforementioned FT-3L material was used as the magnetic alloy ribbon and which had a generally rectangular annular shape with the outside diameter of 80.1 mm×47.6 mm, the inside diameter of 56.3 mm×23.8 mm, and the thickness of 12.5 mm. These magnetic cores were housed in a case which was formed by the upper case and the lower case. The bobbin used included a cylindrical portion around which a lead wire was to be wound, flanges provided at opposite ends of the cylindrical portion, and gear portions provided on the outer side of the flanges for receiving the torque. The bobbin was assembled such that the cylindrical portion was rotatably supported on a linear portion of a case. The bobbin with the inside diameter of 21.2 mm was driven to rotate such that a primary coil (N_{p1}) of 0.5φ-32 turns was wound, and thereafter, a polyester sheet having a base thickness of 25 μm as the insulative sheet 34 was wound three times. Around the resultant structure, a secondary coil (N_{s1}) of 0.5φ-32 turns was wound so as to overlap the polyester sheet, and on the secondary coil, an insulative sheet of a polyester tape was wound around. This procedure was repeated three times to form a coil of 0.5φ-3 lines-32 turns (winding ratio 1:1). FIG. 9(c) is an enlarged view of extracted coil portions. N_{p2} and N_{s2} are wound portions of the second turn of the primary coil and the secondary coil, respectively. N_{p3} and N_{s3} are wound portions of the third turn of the primary coil and the secondary coil, respectively. Such magnetic core and coils were used to form a transformer, and the effective resistance (AC resistance) of the coils was measured. The measurement results are shown in FIG. 10.

[0089] In the entire frequency band of not less than 5 kHz shown in FIG. 10, example 1 in which the coil B was used had a lower effective resistance than comparative example 1 in which the coil A was used. The increase rate of the effective resistance to the increase of the frequency is smaller in the example in which the coil B was used. It can be seen that the increase rate is low particularly in the range of not more than 100 kHz.

[0090] Next, the difference in increase of the temperature under natural air cooling between a transformer which had the configuration shown in FIG. 1 (example) and a transformer in which a conventional ferrite was used (comparative example) was examined. The materials of the magnetic core were the aforementioned FT-3L material for the example and a Mn-Zn ferrite for the comparative example. Note that, in this example (example 2), each of a pair of opposing linear portions of a rectangular case was provided with a bobbin, although a single bobbin was used in the embodiment shown in FIG. 1. The configuration of the magnetic core and the case was the same as that of the transformer shown in FIG. 1. The bobbin was driven to rotate such that a primary coil (N_{p1}) of 0.3φ-3 lines-16 turns was wound, and thereafter, an insulative sheet of a polyester tape was wound around, and over the resultant structure, a secondary coil (N_{s1}) of 0.3φ-3 lines-16 turns was wound so as to overlap the insulative sheet, and another insulative sheet of a polyester tape was wound around over the secondary coil. This procedure was repeated three times to form a coil of 0.3φ-9 lines-16 turns (winding ratio 1:1) at one of the pair of linear portions. Further, the same wire winding operation was carried out on a bobbin attached to the other one of the pair of linear portions. The primary wound wire and the secondary wound wire of the two bobbins were connected in series as shown in FIG. 6, whereby a coil of 3φ-9 lines-32 turns (winding ratio 1:1) was formed.

[0091] On the other hand, in a transformer in which a conventional ferrite was used (comparative example 2), EER-shaped ferrite pieces were joined to form a magnetic core. A bobbin which had an inner circumferential surface shape determined according to the cross-sectional shape of the middle leg of the magnetic core (bobbin for EER53) was prepared. Around this bobbin, a primary coil (N_{p1}) of 0.55φ-3 lines-23 turns was wound, and thereafter, an insulative sheet of a polyester tape was wound around the primary coil. Over the resultant structure, a secondary coil (N_{s1}) of 0.55φ-3 lines-23 turns was wound so as to overlap the insulative sheet, and another insulative sheet of a polyester tape

was wound around over the secondary coil. This procedure was repeated two times to form a coil of 0.55 μ -6 lines-23 turns (winding ratio 1:1).

[0092] As described hereinabove, an insulated transformer of 1:1 was manufactured with the specifications of the switching frequency at 20 kHz and the input of 230 Vrms 9.5 Arms. The volumes of the transformer of the example and the transformer of the comparative example were both $183 \times 10^{-6} \text{ m}^3$. Bm was designed as high as possible in a range which does not cause problems in the operation, such as magnetic saturation, burnout, etc. The results of comparison between the example and the comparative example are shown in Table 1. Note that the "transformer volume" in Table 1 refers to a volume calculated with the product of the maximum dimensions in three directions which are orthogonal to one another (x, y, z directions). Further, the manufactured transformers were mounted to an inverter, and comparison of driving was performed. The results of the core and coil temperature variations with respect to the drive time are shown in FIG. 11.

[Table 1]

	EXAMPLE 2	COMPARATIVE EXAMPLE 2
OPERATION MAGNETIC FLUX DENSITY (mT)	780	200
CORE LOSS (W)	4.24	3.91
COPPER LOSS (W)	6.49	6.20
TRANSFORMER VOLUME ($\times 10^{-6} \text{ m}^3$)	183	183
TRANSFORMER MASS (g)	318	564
MAGNETIC CORE VOLUME ($\times 10^{-6} \text{ m}^3$)	23	87
TEMPERATURE INCREASE COIL SURFACE ($^{\circ}\text{C}$)	43.5	57.8
TEMPERATURE INCREASE CORE SURFACE ($^{\circ}\text{C}$)	37.1	36.4

[0093] Even though the transformer of the example was driven with a magnetic flux density exceeding 0.7 T, which was almost four times that of the transformer of the comparative example, the core loss was generally equal and, as seen from FIG. 11, the temperature at the magnetic core surface did not exhibit a large difference from that of the transformer of the comparative example. That is, it was verified that the transformer of the example can be driven with a high magnetic flux density.

[0094] The temperature at the coil surface was noticeably low in the transformer of the example than in the transformer of the comparative example. It was verified that the configuration of the transformer of the example was also excellent in heat radiation.

[0095] Further, as shown in Table 1, in the transformer of the example, the volume of the magnetic core and the mass of the entire transformer were respectively not more than 1/3 and not more than 2/3 of those of the comparative example. That is, it was found that employing the configuration of the transformer according to an embodiment of the present invention can realize a considerable weight reduction of the transformer. As seen from the fact that the increase of the coil temperature was noticeably smaller in the example, when the transformer is designed such that the increase of the coil temperature is generally equal to that of the comparative example, the configuration of the example enables a greater size reduction.

[0096] Next, in a case where an uncut magnetic core around which a magnetic alloy ribbon (FT-3L material) was wound was used (example 3) and a case where a ferrite magnetic core was used (comparative example 3), a transformer was designed so as to have the minimum volume with the specifications of 10 kHz, 20 kW (200 V 100 Arms) and the winding number ratio of 1:1, under the condition that the temperature increase in natural air cooling was 45 $^{\circ}\text{C}$. Note that, also in the transformer of this example, the arrangement of the magnetic core and the coils is the same as that of the above-described transformer of example 2.

[0097] The transformer of the comparative example was realized by joining long legs of UU cores in a coil form. The magnetic core used was a UU-shape Mn-Zn ferrite piece which had a rectangular cross section. The coil form used was realized by alternately winding the primary coil and the secondary coil around a bobbin which had a rectangular cross section. The results of comparison between the transformer of the example and the transformer of the comparative example are shown in Table 2.

[Table 2]

	EXAMPLE 3	COMPARATIVE EXAMPLE 3
CORE CROSS-SECTIONAL AREA A_e (mm ²)	300	1380
NUMBER OF WINDINGS (T_s)	20	15
OPERATION MAGNETIC FLUX DENSITY (mT)	833	242
CORE LOSS (W)	7.1	15.7
COPPER LOSS (W)	69.1	66.1
TRANSFORMER VOLUME ($\times 10^{-6}\text{m}^3$)	2424	2984
TRANSFORMER MASS (g)	3323	5491
VOLUME RATIO	0.81	1
MASS RATIO	0.61	1

[0098] In the transformer of the example which can be driven with a high magnetic flux density, size reduction and weight reduction, 19% in volume and 39% in mass relative to the transformer of the comparative example, were achieved. It can be seen that noticeable effects were achieved.

[0099] Next, in a case where an uncut magnetic core around which a magnetic alloy ribbon (FT-3L material) was wound was used (example 4) and a case where a cut core of a Fe-based nanocrystalline alloy ribbon was used (comparative example 4), a transformer was designed so as to have the minimum volume with the specifications of 50 kHz, 5 kW (200 V 25 Arms) and the winding number ratio of 1:1, under the condition that the temperature increase in natural air cooling was 45°C. Note that, also in the transformer of this example, the arrangement of the magnetic core and the coils is the same as that of the above-described transformer of example 2.

[0100] The transformer of the comparative example was realized by joining long legs of UU cores in a coil form. The magnetic core used was a UU-shape cut core which had a rectangular cross section and which was made of a FT-3M material (B_s : 1.23 T, B_r/B_s : 0.5) manufactured by Hitachi Metals, Ltd. The coil form used was realized by alternately winding the primary coil and the secondary coil around a bobbin which had a rectangular cross section. The results of comparison between the transformer of the example and the transformer of the comparative example are shown in Table 3.

[Table 3]

	EXAMPLE 4	COMPARATIVE EXAMPLE 4
CORE CROSS-SECTIONAL AREA A_e (mm ²)	75	180
NUMBER OF WINDINGS (T_s)	24	26
OPERATION MAGNETIC FLUX DENSITY (mT)	556	214
CORE LOSS (W)	9.1	10.2
COPPER LOSS (W)	8.5	10.1
TRANSFORMER VOLUME ($\times 10^{-6}\text{m}^3$)	355	430
TRANSFORMER MASS (g)	342	671
VOLUME RATIO	0.82	1
MASS RATIO	0.51	1

[0101] In the transformer of the example which can be driven with a high magnetic flux density, size reduction and weight reduction, 18% in volume and 49% in mass relative to the transformer of the comparative example, were achieved. It can be seen that noticeable effects were achieved.

INDUSTRIAL APPLICABILITY

[0102] A transformer according to an embodiment of the present invention is suitably used in, for example, a switched mode power supply or insulated inverter whose drive frequency is not less than 10 kHz and output is not less than 5 kW.

REFERENCE SIGNS LIST**[0103]**

5	100:	transformer
	1:	case
	2, 12, 16, 21, 27, 31:	primary coil
	3, 13, 17, 22, 28, 32:	secondary coil
	4, 14, 18, 19, 23, 24, 26, 30:	bobbin
10	5, 15, 20, 25, 29, 33:	magnetic core
	6:	linear portion
	7:	cylindrical portion
	8:	flange
	9:	gear portion
15	10:	recess
	11:	protrusion
	34:	sheet-like insulator

20 Claims**1.** A transformer, comprising:

25 an uncut magnetic core formed by winding or layering a magnetic alloy ribbon, the uncut magnetic core forming a closed magnetic path;
 a protector member covering at least part of the magnetic core;
 a primary coil and a secondary coil; and
 at least one bobbin around which a lead wire which forms the primary coil and the secondary coil is to wound, wherein the at least one bobbin includes a cylindrical portion which has a circumferential surface around which
 30 the lead wire is to be wound, a pair of flanges arranged so as to sandwich the circumferential surface in an axial direction of the cylindrical portion, and at least one gear portion provided on an outer side of at least one of the pair of flanges so as to be spaced away from the flange, the at least one bobbin being supported on the cylindrical portion so as to be rotatable around the protector member, and
 a wound portion of a lead wire which forms the primary coil and a wound portion of a lead wire which forms the
 35 secondary coil are arranged alternately in a radial direction of the cylindrical portion.

2. The transformer of claim 1, wherein the at least one bobbin includes a plurality of bobbin members which are assembled around the protector member so as to sandwich the protector member, and each of the plurality of bobbin members includes a part of the cylindrical portion.

40 **3.** The transformer of claim 1 or 2, wherein in the at least one bobbin, lead wires of respective ones of a plurality of wound portions of a lead wire which forms the primary coil which overlaps via a wound portion of a lead wire which forms the secondary coil are connected in parallel on an outer side of the flanges, and lead wires of respective ones of a plurality of wound portions of a lead wire which forms the secondary coil which overlaps via a wound portion of
 45 a lead wire which forms the primary coil are connected in parallel on an outer side of the flanges.

4. The transformer of claim 1 or 2, wherein
 the at least one bobbin includes a plurality of bobbins, and
 the primary coil and the secondary coil are each divided into a plurality of sub-coils which are connected in parallel
 50 or in series, and the plurality of sub-coils are provided to the plurality of bobbins.

5. The transformer of any of claims 1 to 4, wherein the magnetic alloy ribbon has magnetic characteristics such that a saturation magnetic flux density B_s is not less than 1.0 T, and a ratio of a residual magnetic flux density B_r to the saturation magnetic flux density B_s , B_r/B_s , is not more than 0.3.

55 **6.** The transformer of any of claims 1 to 5, wherein an insulator in the form of a sheet is provided between a wound portion of the primary coil and a wound portion of the secondary coil.

7. The transformer of any of claims 1 to 4, wherein in at least one of the pair of flanges, a lead wire passage portion is provided for providing on an outer side of the flanges an end portion of a lead wire that is wound around a circumferential surface of the cylindrical portion, and the lead wire passage portion includes a recess or hole which allows passage of the lead wire at a position radially inner than an outer circumferential edge of the flanges.

8. The transformer of claim 7, wherein the lead wire passage portion includes a pair of recesses which are arranged so as to sandwich the cylindrical portion when seen in an axial direction of the cylindrical portion, and an end portion of the lead wire which forms the primary coil is provided on an outer side of the flanges via one of the pair of recesses, and an end portion of the lead wire which forms the secondary coil is provided on an outer side of the flanges via the other one of the pair of recesses.

9. The transformer of claim 7 or 8, wherein the at least one bobbin further includes a restricting section which has a surface for hindering an end portion of the lead wire provided on an outer side of the flanges via the lead wire passage portion from moving radially outward of the cylindrical portion when the bobbin is rotated.

10. The transformer of any of claims 1 to 9, further comprising a pole-like protrusion protruding radially outward of the cylindrical portion from a surface of the flanges.

11. The transformer of any of claims 1 to 10, wherein the protector member is a case for housing the magnetic core.

12. The transformer of any of claims 1 to 11, wherein the at least one bobbin has an outer circumferential surface between the flange and the gear portion, and a diameter of the outer circumferential surface is equal to a diameter of a circumferential surface of the cylindrical portion.

13. A power supply device, comprising the transformer as set forth in any of claims 1 to 12.

14. The power supply device of claim 13, wherein the power supply device is an insulated inverter or insulated switched mode power supply whose drive frequency is 10 to 50 kHz and output is not less than 5 kW.

15. A method for manufacturing a transformer, comprising:

the first step of attaching a protector member to an uncut magnetic core, the uncut magnetic core being formed by winding or layering a magnetic alloy ribbon, the uncut magnetic core forming a closed magnetic path;
the second step of attaching at least one bobbin, the at least one bobbin including a cylindrical portion which has a circumferential surface around which a lead wire is to be wound, a pair of flanges arranged so as to sandwich the circumferential surface in an axial direction of the cylindrical portion, and at least one gear portion which is provided on an outer side of at least one of the pair of flanges so as to be spaced away from the flange, the at least one bobbin being attached so as to be rotatable around the protector member at the cylindrical portion; and
the third step of winding a lead wire around the circumferential surface of the cylindrical portion by rotating the bobbin via the gear portion, thereby forming a primary coil and a secondary coil around the cylindrical portion, wherein the third step includes the step of forming a wound portion of a lead wire which forms the primary coil and a wound portion of a lead wire which forms the secondary coil alternately in a radial direction of the cylindrical portion.

16. The method of claim 15, wherein the at least one bobbin includes a plurality of bobbins, and the primary coil and the secondary coil are each divided into a plurality of sub-coils which are connected in parallel or in series, and the plurality of sub-coils are provided to the plurality of bobbins.

17. The method of claim 15 or 16, wherein at least one of the pair of flanges has a pair of recesses which are arranged so as to sandwich the cylindrical portion when seen in an axial direction of the cylindrical portion, and the third step includes the step of winding the lead wire which forms the primary coil while an end portion of the lead wire is provided on an outer side of the flanges from one of the pair of recesses, and the step of winding the lead wire which forms the secondary coil while an end portion of the lead wire is provided on an outer side of the flanges from the other one of the pair of recesses.

18. The method of any of claims 15 to 17, wherein in the third step, in forming a wound portion of the lead wire, an end portion of the lead wire is provided in a gap between the flange and the gear portion.

19. The method of claim 18, wherein

the at least one bobbin further includes further includes a restricting section which has a surface for hindering an end portion of the lead wire provided on an outer side of the flanges from moving radially outward of the cylindrical portion, and

in the third step, in forming a wound portion of the lead wire, an end portion of the lead wire is provided at a position inner than the restricting section in a radial direction of the cylindrical portion.

20. The method of any of claims 15 to 18, wherein

the at least one bobbin has a pole-like protrusion protruding radially outward of the cylindrical portion from a surface of the flanges, and

the third step includes the step of tying an end portion of the lead wire around the protrusion.

FIG. 1

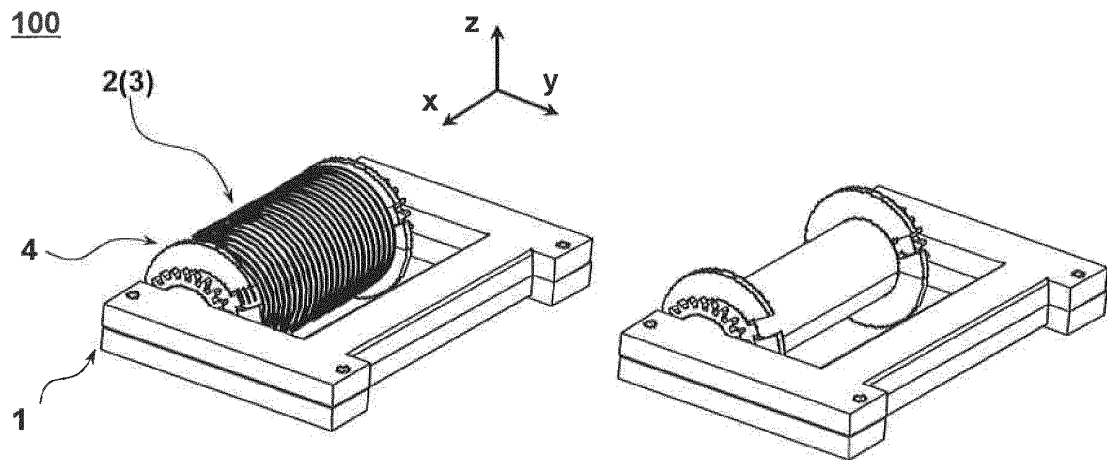


FIG. 2

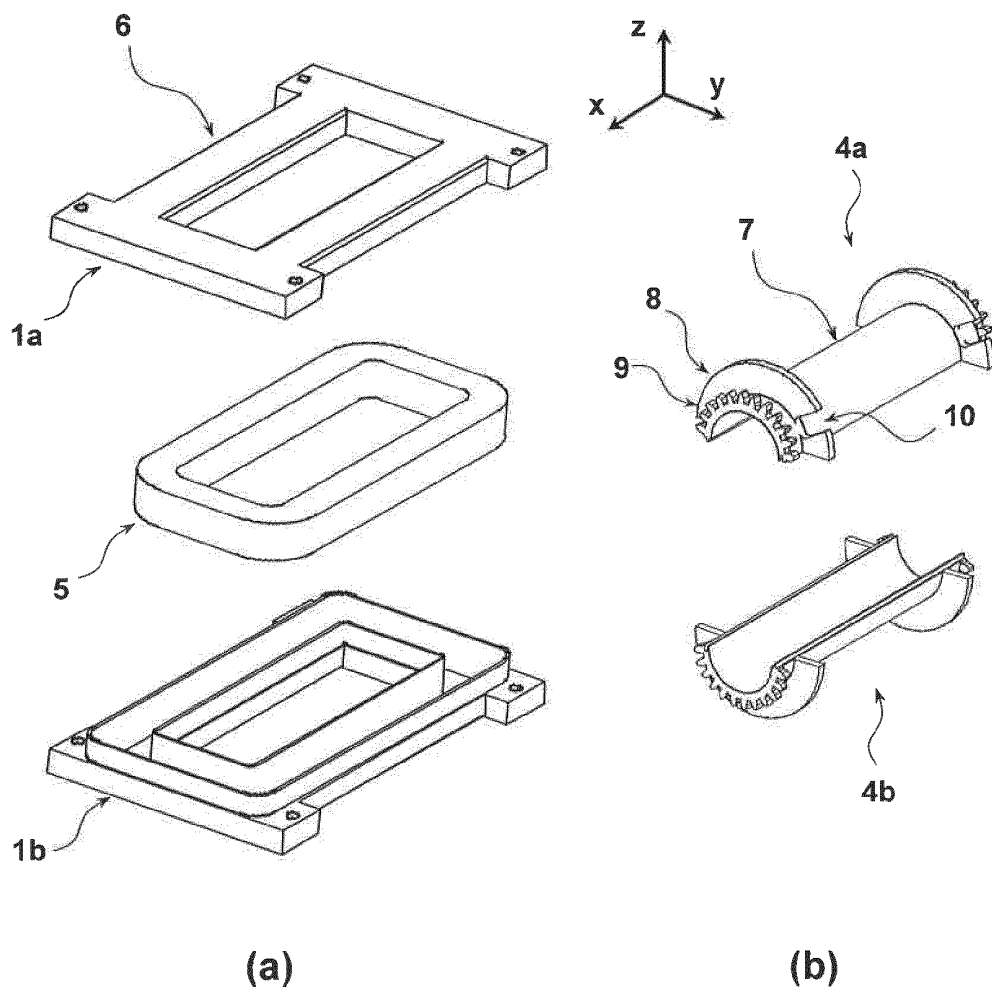


FIG. 3

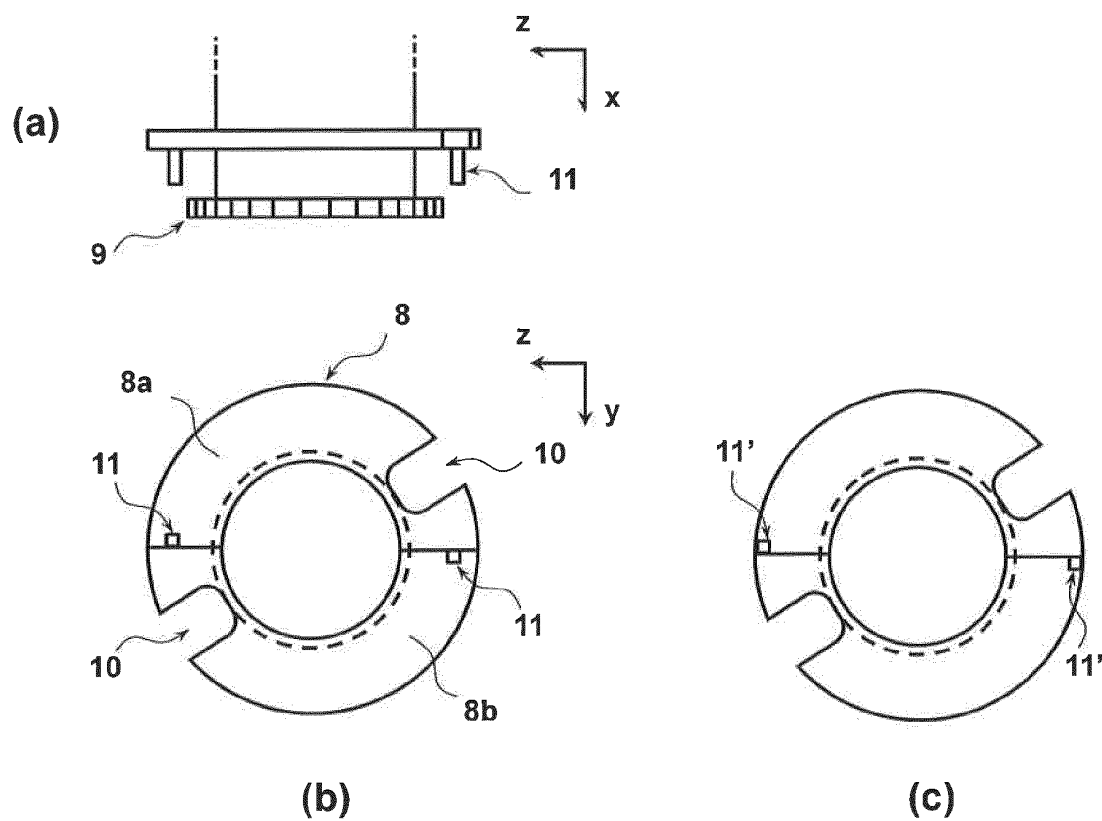


FIG. 4

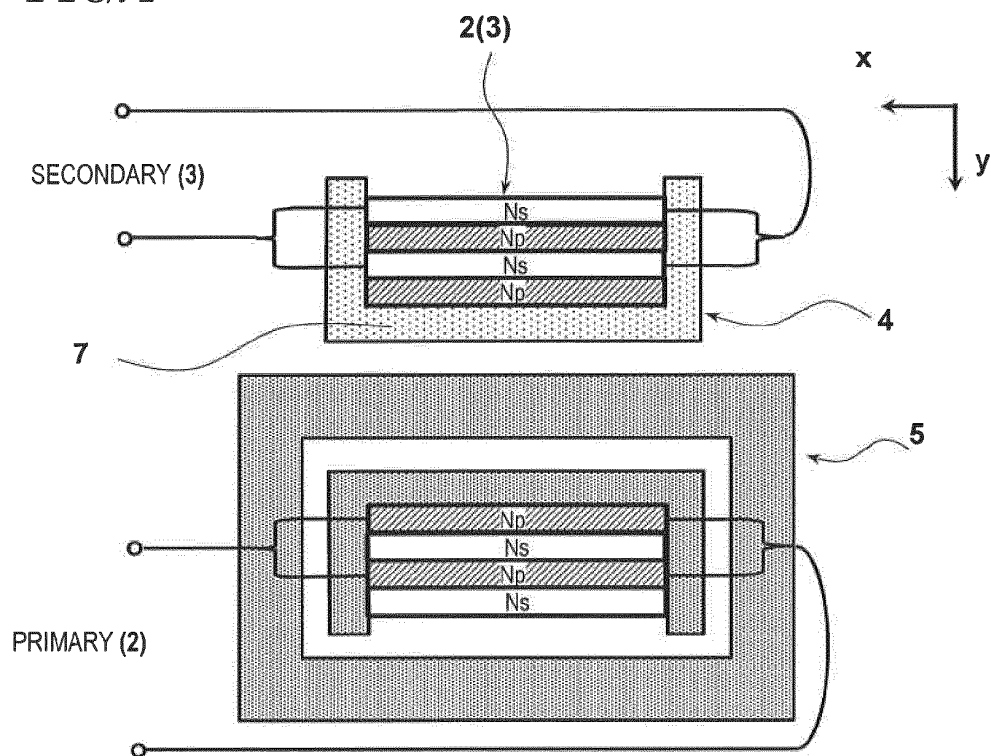


FIG. 5

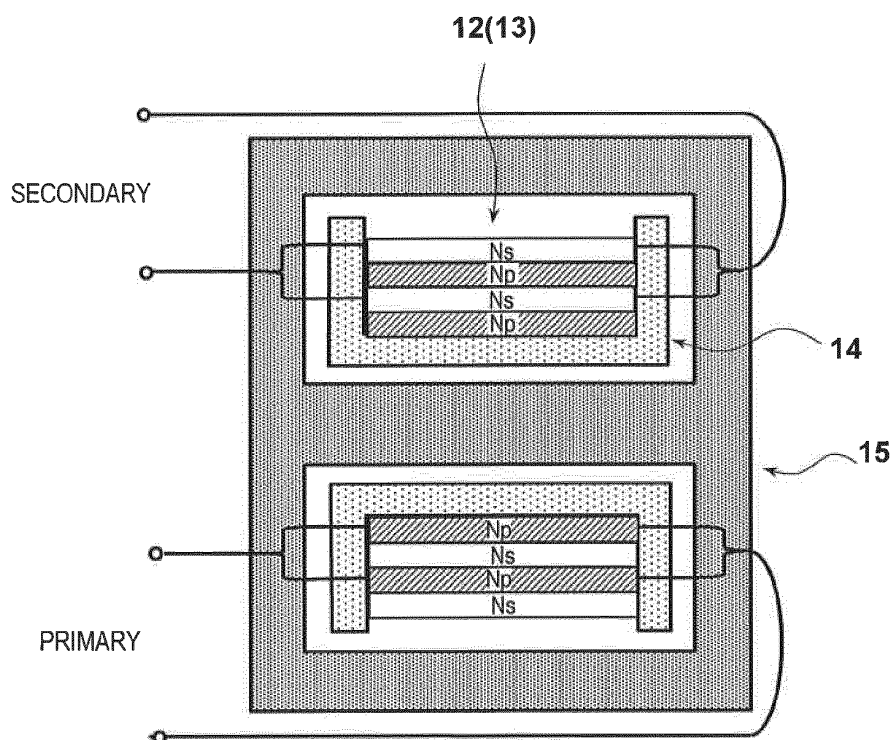


FIG. 6

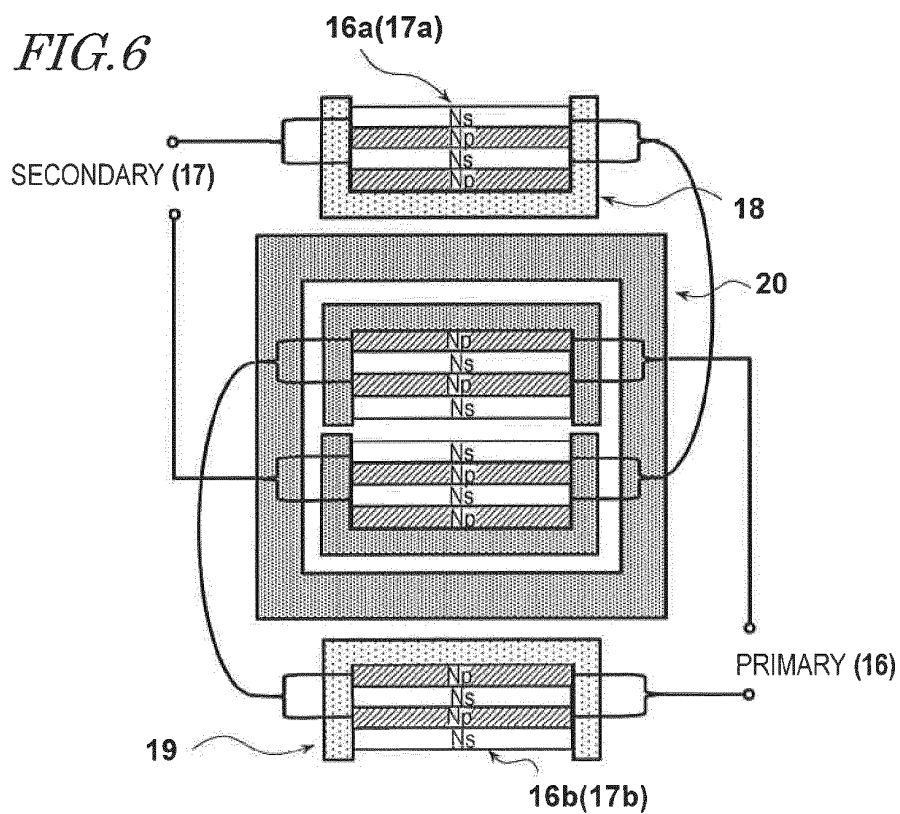


FIG. 7

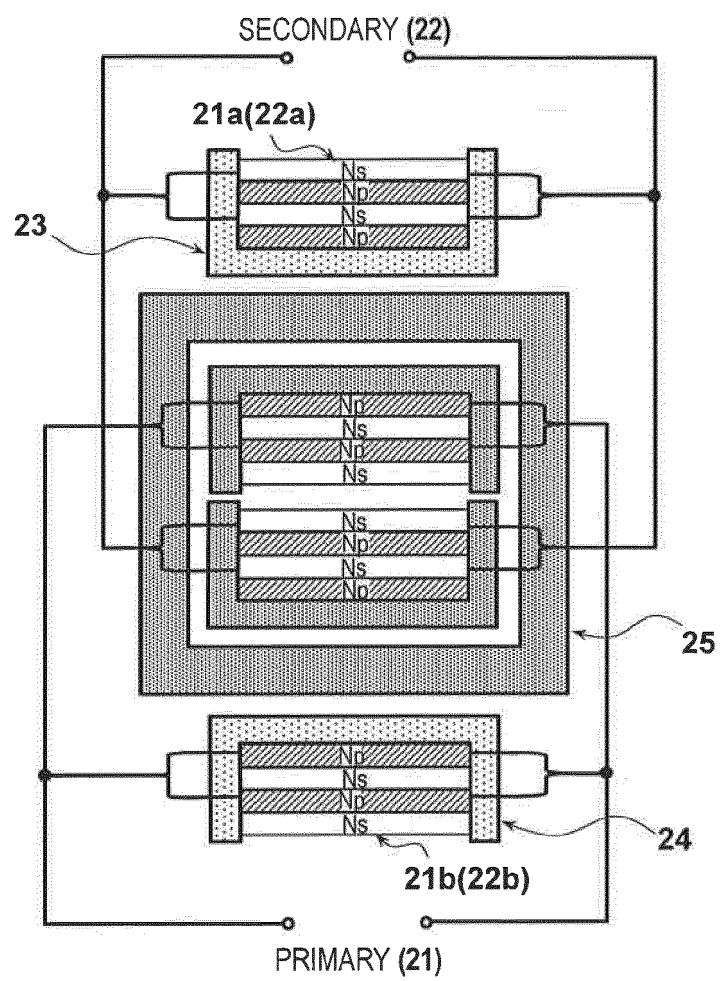


FIG. 8

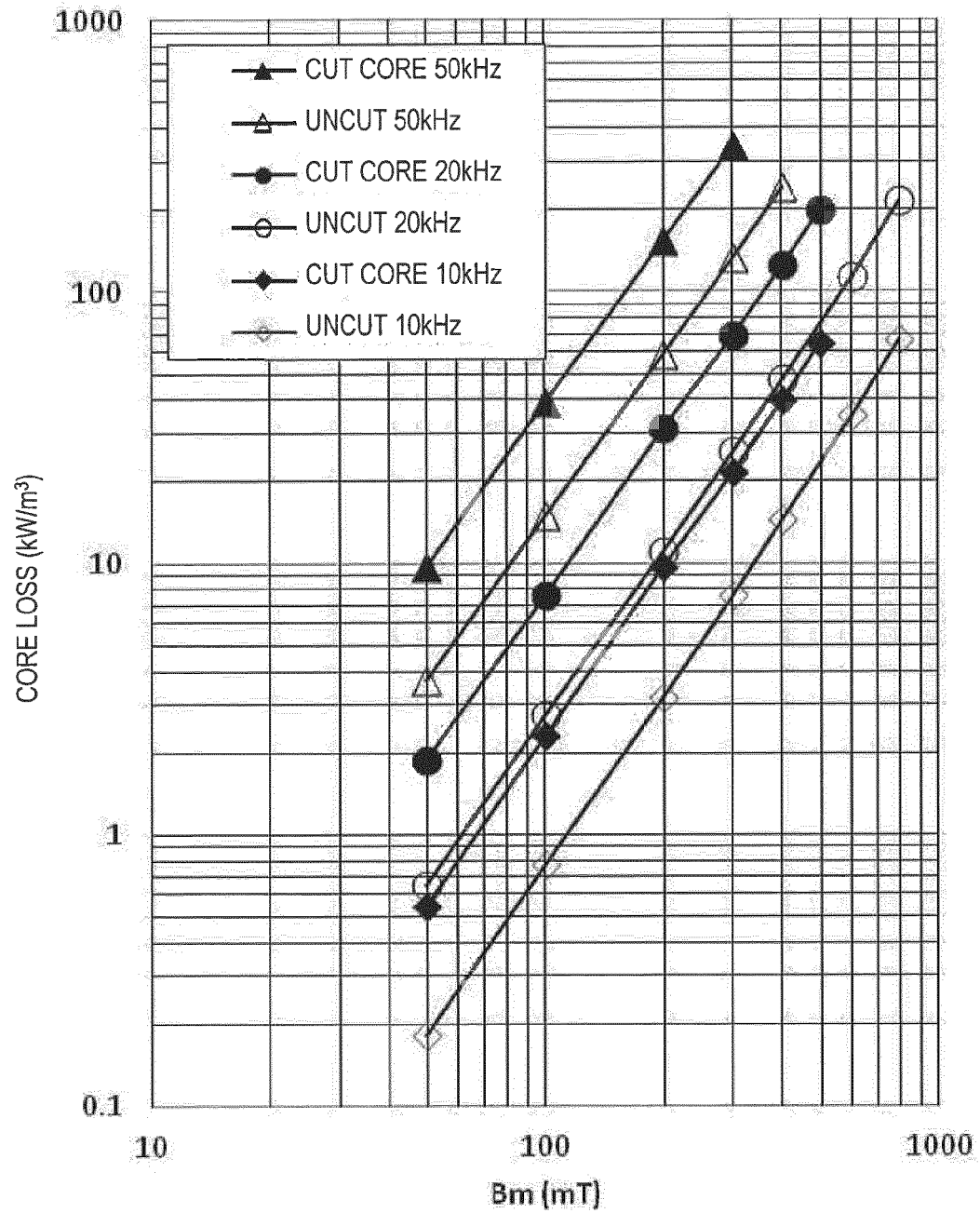
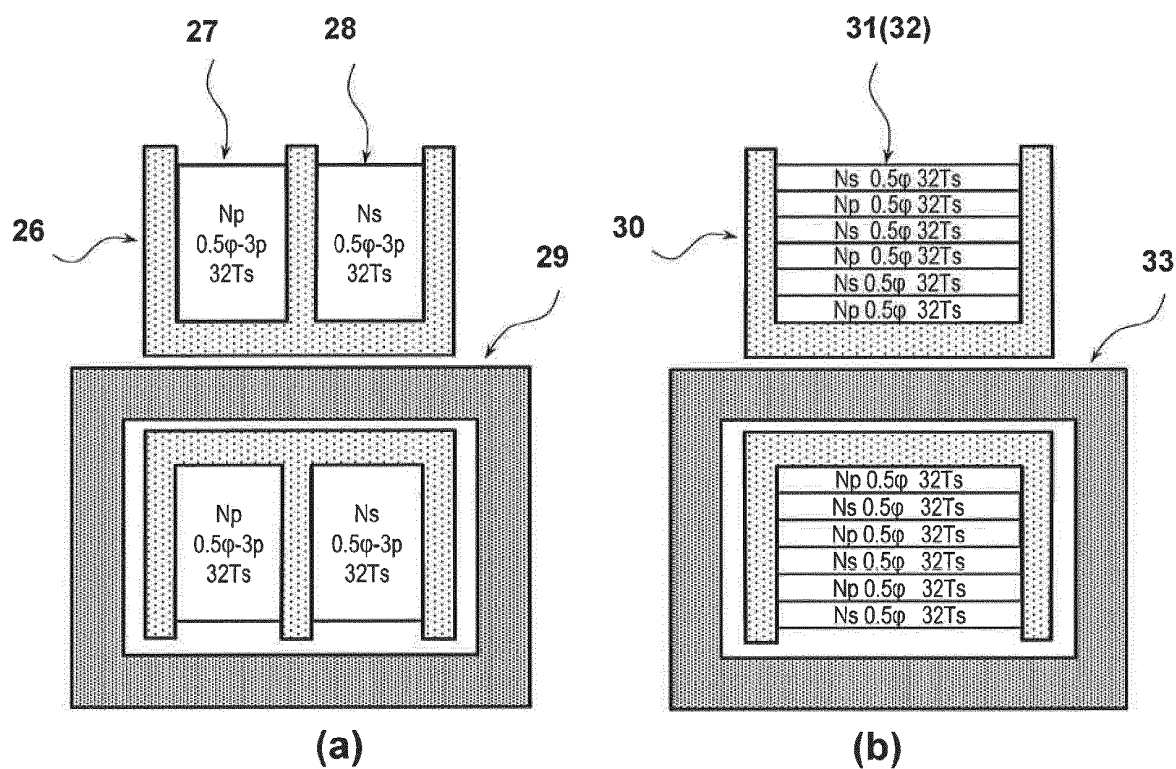


FIG. 9



Ns3	0.5-1p 32Ts	1 LAYER
Np3	0.5-1p 32Ts	1 LAYER
Ns2	0.5-1p 32Ts	1 LAYER
Np2	0.5-1p 32Ts	1 LAYER
Ns1	0.5-1p 32Ts	1 LAYER
Np1	0.5-1p 32Ts	1 LAYER

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Np1	0.5-1p 32Ts	1 LAYER
Ns1	0.5-1p 32Ts	1 LAYER
Np2	0.5-1p 32Ts	1 LAYER
Ns2	0.5-1p 32Ts	1 LAYER
Np3	0.5-1p 32Ts	1 LAYER
Ns3	0.5-1p 32Ts	1 LAYER

(c)

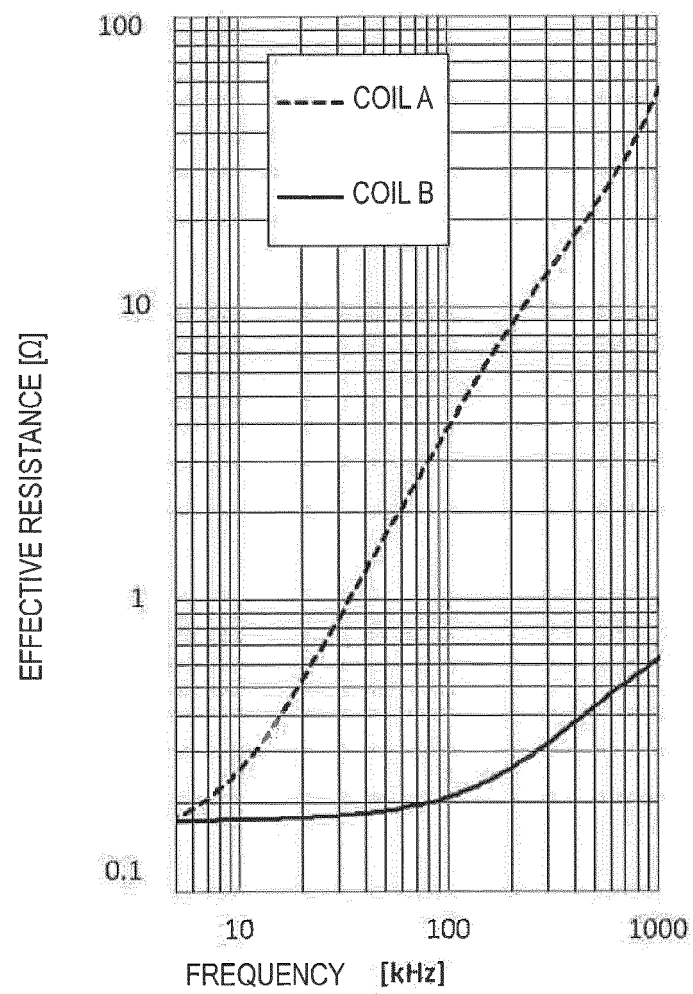
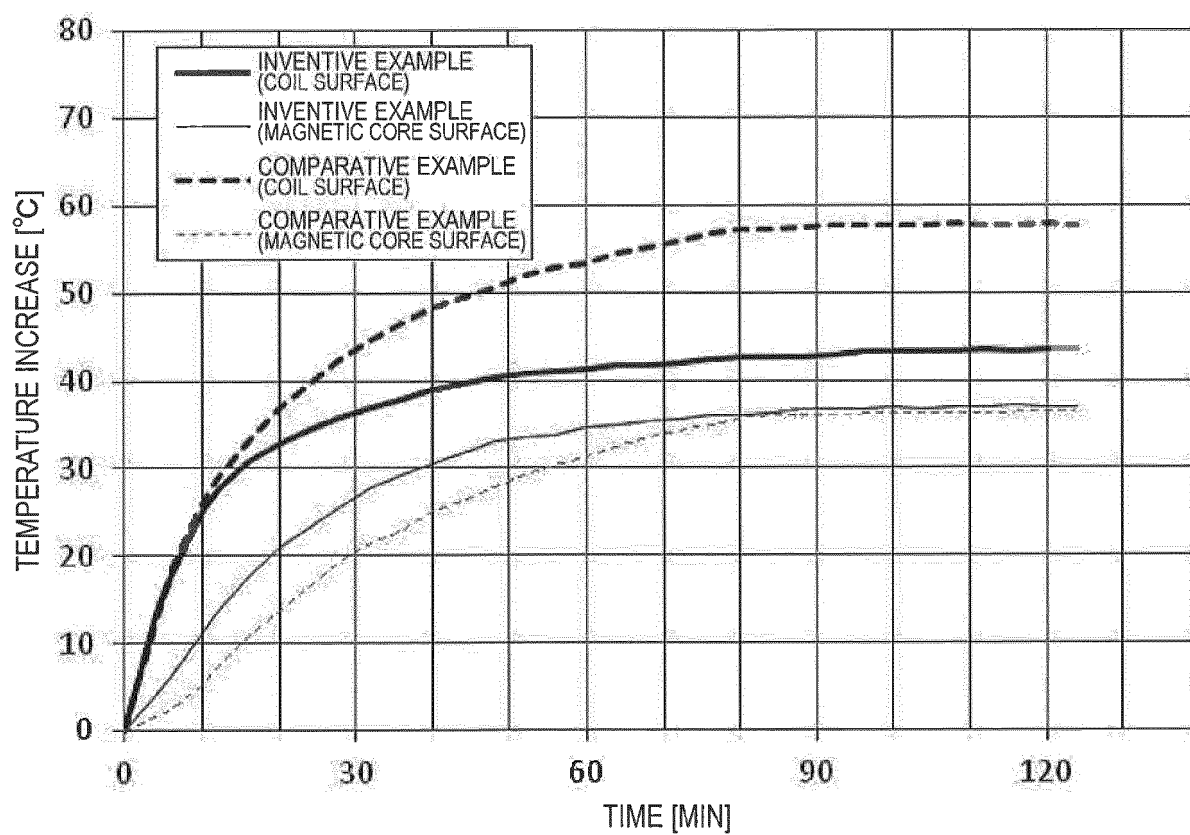
FIG. 10

FIG. 11



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/052035

A. CLASSIFICATION OF SUBJECT MATTER

H01F30/00(2006.01)i, H01F27/28(2006.01)i, H01F27/29(2006.01)i, H01F41/08(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)

H01F30/00, H01F27/28, H01F27/29, H01F41/08

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 1996-2015

Kokai Jitsuyo Shinan Koho 1971-2015 Toroku Jitsuyo Shinan Koho 1994-2015

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	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 21400/1979(Laid-open No. 122329/1980) (Matsushita Electric Industrial Co., Ltd.), 30 August 1980 (30.08.1980), specification, page 3, line 10 to page 4, line 14; fig. 2 to 4 (Family: none)	1-20

☒ 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
07 April 2015 (07.04.15)

Date of mailing of the international search report
14 April 2015 (14.04.15)

Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigasaka, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/052035

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 74758/1984 (Laid-open No. 187522/1985) (Matsushita Electric Works, Ltd.), 12 December 1985 (12.12.1985), specification, page 6, line 4 to page 7, line 6; specification, page 8, line 9 to page 9, line 6; fig. 1 to 4 (Family: none)	1-20
Y	JP 2-178905 A (Matsushita Electric Industrial Co., Ltd.), 11 July 1990 (11.07.1990), page 3, lower left column, line 2 to page 4, upper left column, line 19; fig. 1, 3 to 4 (Family: none)	1-20
Y	JP 6-283363 A (Nippon Steel Corp.), 07 October 1994 (07.10.1994), claim 3; paragraphs [0010], [0012], [0018] to [0019]; fig. 3, 6 (Family: none)	1-20
Y	CD-ROM of the specification and drawings annexed to the request of Japanese Utility Model Application No. 89703/1991 (Laid-open No. 41124/1993) (Tokin Corp.), 01 June 1993 (01.06.1993), paragraphs [0013] to [0017]; fig. 1 to 3 (Family: none)	9-10, 19-20
Y	JP 2000-182869 A (Citizen Electronics Co., Ltd.), 30 June 2000 (30.06.2000), paragraph [0004]; fig. 8 (Family: none)	9-10, 19-20

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 4085714 A [0005]