The present invention relates to electrical apparatus for alternating current and more particularly to an improved construction of an annular core and an endless winding thereon.

The present application is a continuation-in-part of my copending application, entitled Voltage Regulating Apparatus, Serial No. 467,781, filed November 9, 1954, now abandoned.

The above-mentioned parent application discloses and claims a variable autotransformer designed to control relatively large amounts of electrical power, i.e., from 5 kva. upwards, and in which there are a plurality of windings encircling a magnetic core. At least one of the windings has its own magnetic core which also encircles a portion of the first-mentioned core and the winding is toroidally wound on its core to form a closed or endless winding. The surface of the winding is formed to have a smooth commutating surface on which a brush rides to be in electrical engagement with the turns of the winding. Since the electrical current controlled by the autotransformer passes through the toroidal winding, the winding has to have sufficient cross-sectional area to carry at least the rated current of the device and in addition have a smooth surface for engagement with the brush. Conventional practice of winding the core from an endless length of wire or flat stock has not been found practical and feasible because having the necessary cross-sectional area is too stiff to wind on the relatively small annular core. Moreover, in order to provide a smooth commutating surface (which is formed by cutting away a cross-sectional portion of a length of each turn), the wire has to be initially of a larger area than the minimum required.

An object of the present invention is to provide an endless winding having a relatively large current carrying capacity and a smooth commutating surface with the winding being toroidally wound on a relatively small annular core.

Another object of the present invention is to provide a winding about an annular core in which each turn of the winding is composed of two distinct elements, with the elements of each turn being interlocked with adjacent turns to form a closed winding.

Another object of the present invention is to provide a winding of the above type in which all the turns are identical, in which the elements of each turn may be economically manufactured, and in which the winding is simply and easily assembled.

Another object of the present invention is to provide in an annular core of magnetic material which encircles a portion of another core having magnetic flux therein, for the prevention of circulating currents being induced in the annular core.

In carrying out the present invention, to attain the above objects there is provided an annular core composed of a plurality of identical magnetic metallic rings coaxially positioned together to form a magnetic core having a cross-sectional shape which is preferably substantially rectangular. An endless winding consisting of a plurality of individual turns is toroidally wrapped about the core with each turn of the winding being composed of two elements formed from strips of bendable sheet copper.

In one embodiment of the invention one of the elements is a U-shaped member having its legs angularly displaced a distance which is equal to the arcuate displacement of each turn and interconnecting a leg of one U-shaped portion and an opposite leg of another are straight, substantially flat pieces. In another embodiment, the legs of the U-shaped portion are radially aligned while the substantially flat member is shaped to have its interlocking end portions angularly displaced a distance which is equal to the arcuate displacement of each turn. The ends of the legs and the ends of the pieces are shaped to interlock to produce a closed winding in both embodiments. Either the U-shaped portion of the straight flat pieces easily provide a smooth commutating surface.

In the specific embodiment shown, the annular magnetic core is adapted to encircle a portion of another magnetic core and hence the flux in the latter core would tend to induce circulating current in the annular core. In order to eliminate the circulating current in the annular core, each of the rings forming the core has a slit therein to make the ring discontinuous. The rings are coaxially mounted adjacent each other with the slits of the rings being peripherally spaced. To prevent adjacent rings from forming a complete path, in one embodiment of the invention a piece of insulating material such as varnished paper is positioned between each ring to electrically insulate the rings, while in another embodiment the insulating material is positioned in each slit to extend on one side and the other side of each ring. Accordingly, each ring thus forms an incomplete conductive path and the rings are insulating with respect to each other so that adjacent rings cannot combine to form a complete path.

Other features and advantages will hereinafter appear.

In the drawing:

Figure 1 is a front view of the winding and core of the present invention, shown partly in section.

Fig. 2 is a perspective view of only a determinate length of the winding on a length of the core.

Fig. 3 is a front view of the core.

Fig. 4 is a perspective view of at least one complete turn of the winding of the present invention.

Fig. 5 is a perspective view of at least one complete turn of a second embodiment of a winding.

Fig. 6 is a front view of a second embodiment of the core.

Fig. 7 is an end view of the core of Fig. 6.

Referring to the drawing, the toroidal winding of the present invention is indicated by the reference numeral 10 and is shown wrapped about annular magnetic core 11. The core as shown in Fig. 3 is composed of a plurality of rings 12 which are formed from paramagnetic material, such as silicon iron. Each of the rings is made discontinuous by a chordal slit 13. The rings are coaxially placed together as shown, with the slit of each ring being angularly spaced about the circumference of the core, as for example 13a, 13b, 13c, etc. Since the core, as disclosed in my previously mentioned application, circumscribes a portion of another annular core 11a (indicated in dotted lines in Fig. 1), when there is flux in the core 11a it tends to induce a circulating current in each of the rings 12. This circulating current of the present invention is prevented from occurring by the slits 13.

In order to assure discontinuity of each ring 12 and prevent electrical contact between adjacent rings, a flat ring 14 (see Fig. 2) of thin insulating material is positioned between each ring 12. In the embodiment of the core shown in Figs. 6 and 7, each metal ring 13a has a radial slit 14a and the insulation is provided by an arcu-
ate length 15 of approximately 360° of insulating material. The rings 13a have their slits 14a spaced about the circumference of the rings and the length 15 is threaded through the slits. The insulating material 14 or 15, in addition to providing discontinuity of the ring, further prevents any circulating current from jumping from one ring to another to form a complete circular path. As shown, the slits and the insulating element 15 are evenly displaced about the periphery of the ring which provides a substantially constant magnetic path throughout and a more compact core.

The toroidal winding 10, according to the present invention, comprises a series of generally U-shaped segments 16 progressively interconnected by crossbars 17 to cooperatively form the annularly advancing endless winding 10 having generally rectangular shaped turns in closely conforming relation about the core 11 therebeneath, these segments and crossbars being shaped from sheet copper or other suitable electrically conductive material. Each segment 16 has a pair of spaced substantially parallel side legs 18 and 19 interconnected at their inner ends by a tight or cross portion 20. One of the legs, as 19, is angularly disposed rearwardly with respect to a core radius passing centrally through the portion 20 and the other leg, as 18, is correspondingly angularly disposed forwardly of the same core radius to provide the required lead for each turn of the winding about the core 11. The outer ends of the legs 18 and 19, which are slightly arauce in generally concentric relation to the core are respectively provided, intermediate their ends, with transverse grooves 21 and 22. Each crossbar 17 extends between a leg of one segment and the leg of the next segment and has end projections 23 and 24 respectively interfitting within the corresponding grooves.

To assure good electrical connection between the segments 16 and crossbars 17, which cooperatively form the endless toroidal winding around the core, it is preferred to solder together the interengaging segments and crossbars. With this arrangement the crossbars of the turns form a smooth commutating surface for engagement by a contact brush (not shown).

While in the embodiment hereinafter specifically described, the crossbars and tight portion have been referred to as straight, they are actually slightly curved to conform to the circular portions of the core. Though crossbars have been shown as covering the peripheral surface of the core, it is within the scope of the present invention to mount the crossbars so that they form a commutating surface on a side of the core. In such a construction the crossbars, instead of being substantially rectangular, would be substantially trapezoidal with the innermost base having lesser width, and curving of the bars to fit the periphery of the core would be obviated. An insulating tape or the like (not shown) is preferably progressively wrapped about the core to insulate it from the winding 10 formed thereover.

In the embodiment of the toroidal winding shown in Fig. 5, the U-shaped segments 16a have their legs 18 and 19 radially aligned while the crossbars 17a have their end portions circumferentially spaced a distance equal to the circular length of a turn. Otherwise this embodiment of the winding is the same as that previously described.

Each of the turns is shown as being spaced from each other to prevent short-circuiting between turns. If desired, insulating material such as mica, varnish, plastic, etc. may be positioned in the spaces to positively prevent short-circuiting.

It will thus be appreciated that the winding formed with the above described segments and crossbars provides a closed toroidal winding having a large current carrying path. Additionally, the use of easily formed segments and crossbars which conveniently interfit with each other enables the winding to be economically formed and fabricated about a relatively small annular core, though, of course, they may also be used on relatively large cores, if desired. Moreover the winding has a smooth commutating surface on which a brush may ride, formed by the crossbars. Thus the present invention provides for an endless toroidal winding which may be easily positioned on an annular core. The core is also formed to prevent a complete conductive path for circulating current which would be induced therein when the core circumvents a second core carrying magnetic flux.

Variations and modifications may be made within the scope of the claims and portions of the improvements may be used without others.

I claim:

1. An electrical device comprising an annular core adapted to surround a portion of a ferromagnetic core having magnetic flux therein, said annular core comprising a plurality of rings of ferromagnetic material in adjacent stacked relation, insulating material between said rings, each of said rings having a cut therethrough in angularly spaced relation to the cuts through adjacent rings, a closed winding toroidally wound about the annular core, and in which the insulating material consists of an arcuate length of thin strip that is threaded through the slot of each ring with the strip engaging opposite sides of each ring adjacent the slot.

2. A core for an electrical device comprising a plurality of thin laminations of ferromagnetic material, each of said laminations being substantially identical in shape and being a closed figure defining a central aperture except for being formed to provide a slot extending from the central aperture to the periphery, said laminations being stacked together to form the core having a cross-section identical to the shape of the core and a thickness slightly greater than the sum of the thicknesses of the laminations, the slot of each lamination being displaced from the slots of adjacent laminations and insulating means extending at least partially between each lamination to prevent a closed conductive path between laminations, and in which the slots are disposed to be substantially evenly spaced about the periphery of the core, the insulating means passing through each slot, with the insulating means being a single strip of thin insulating material having a shape corresponding to the shape of a lamination and being threaded through the slots.

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