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METHOD OF MAKING MAGNETIC TOROIDS

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FIG. 1.

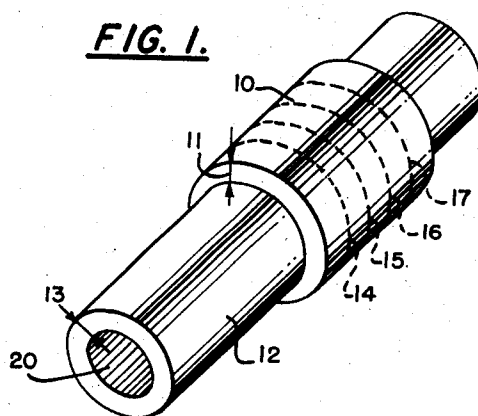


FIG. 2.

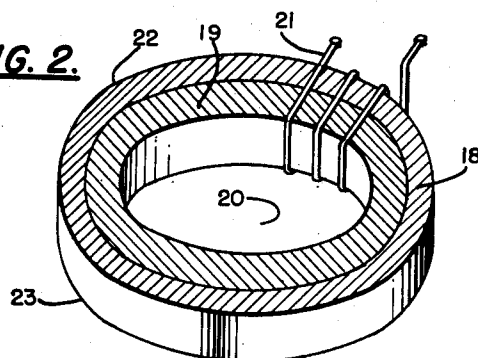
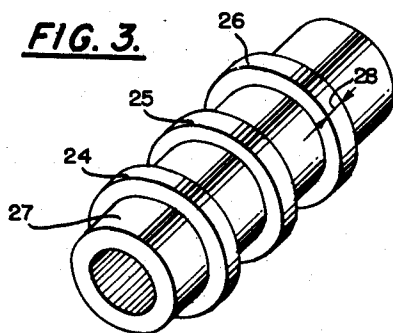


FIG. 3.



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METHOD OF MAKING MAGNETIC TOROIDS

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The present invention relates to novel core structures for use in magnetic devices and is more particularly concerned with a method of manufacturing small volume toroids of novel configuration for use in such devices.

It should be noted before proceeding with the present discussion that the method or techniques hereinafter described, as well as the core configuration to be discussed, may be employed in the manufacture of magnetic cores of any size. These techniques find particular utility, however, in the provision and fabrication of small-volume magnetic toroidal cores. As is well known, it is often desired that the magnetic core to be used in a device such as a magnetic amplifier, a pulse transformer, a magnetic memory circuit, or in various other magnetic systems, be of very small size. In the past, this size limitation has produced a considerable problem in core fabrication, inasmuch as, when small volumes of magnetic material are being used, the core materials are most difficult to work with. In addition, inasmuch as the small volumes of magnetic materials which are often desired for use in magnetic devices of the types mentioned before, have relatively little inherent strength, it is usually necessary that the said small volumes of magnetic materials be combined with a non-magnetic supporting structure of greater structural strength, and again the requirement that such a supporting structure be supplied in an extremely small device augments the problems of fabrication. It has accordingly been found that, as a matter of practice, when prior art techniques are employed in the fabrication of small volume magnetic cores, it is most difficult to make such cores in large quantity by anything resembling a mass production technique, and because of this factor the cost of such cores and of the magnetic devices employing such cores is relatively high.

It is accordingly an object of the present invention to provide a method for manufacturing magnetic cores, which method permits greater ease in working with the several core constituents.

Still another object of the present invention resides in providing a method of working with magnetic materials, in the manufacture of magnetic cores, in such a way that the magnetic core material receives structural support from a core supporting structure during the actual fabrication of the combined core.

A still further object of the present invention resides in the provision of a method for manufacturing small volume magnetic toroids, which method permits for mass production of such toroids and for decreased cost of individual toroids.

In providing the foregoing objects and advantages of the present invention, I employ a method of fabricating a novel magnetic toroid which comprises the steps of starting with a relatively thick tube of magnetic material, inserting and fastening into the said tube a further tube of non-magnetic material to provide support for the magnetic material, grinding or otherwise reducing the thickness of the magnetic tube so mounted, and slicing the

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composite structure into individual toroids of desired cross dimension.

The foregoing objects, advantages, and practice of my invention will become more readily apparent from the following description and accompanying drawings, in which:

Figure 1 is a perspective view of a magnetic tube and non-magnetic support assembled in accordance with the preliminary steps of the present invention.

Figure 2 is a representation of a composite magnetic core structure effected by the method of the present invention, and

Figure 3 depicts a modification of the present invention wherein a plurality of magnetic tubes or toroids are employed in place of the single tube shown in Figure 1.

Referring now to the several figures shown, it will be seen that I first provide a tube of magnetic material 10, which tube 10 has a thickness 11 substantially larger than that desired in the final magnetic toroid. The tube 10 may be fabricated of any material exhibiting desired magnetic properties, such as sintered ferrites, or of other magnetic materials such as 50-50 Nickel Iron (Deltamax, Orthonik, etc.) or 4-79 Moly-Permalloy. These latter magnetic materials may exhibit flux-current curves which are substantially rectangular in configuration and therefore may be employed when such a flux-current curve is desired of the final magnetic toroid. Into the central opening of the tube 10 I insert a further tube 12 of a non-magnetic material. The tube 12 is selected to have a thickness 13 such as to exhibit a structural strength consonant with the requirements of the final structure, and the diameter of the tube 12 is so chosen that the non-magnetic tube 12 fits closely into the tube 10 of magnetic material. The tube 12 is then preferably cemented in place within the magnetic tube 10 to effect a composite structure as shown in Figure 1.

Non-magnetic tube 12 may be made of a variety of materials, for instance of an insulating material such as a ceramic or an appropriate fibrous material. The tube 12 may further be fabricated of a non-magnetic metal such as 18-8 stainless steel, type 304; Inconel; B-Monel; K-Monel; R-Monel; 315 stainless steel; Nichrome; or metallic titanium. When the magnetic material used for tube 10 comprises a ferrite, it has also been found that the supporting tube 12 may be fabricated of brass or of other relatively low melting point metals and alloys. When a non-magnetic metal supporting structure is employed for tube 12, the cement utilized in cementing the tube in place may preferably be of an electrical insulating nature, or a layer of insulation may preferably be interposed between the external peripheral surface of non-magnetic tube 12 and the internal surface of the magnetic tube 10. It has been found that this requirement of insulation is not mandatory, however, and thus, for many magnetic applications utilizing the magnetic materials enumerated above, no insulation need in fact be provided. This is especially the case when the magnetic material comprising tube 10 is a ferrite, and under such circumstances the requirement of insulation between the magnetic tube and the supporting structure may, if desired, be dispensed with. It should further be noted that if the tube 12 is in fact chosen of a non-magnetic metal, the actual method of fabricating the composite structure shown in Figure 1 may be varied so that the tube 12 and the magnetic tube 10 mounted thereon are annealed simultaneously, either before or after the reduction and slicing steps to be described.

Once the insulating or non-magnetic tube 12 is inserted into the magnetic tube 10 and cemented in place as shown in Figure 1, the composite structure is mounted and rotated between centers, for instance on a lathe, and the external peripheral surface of the said tube 10

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is then preferably ground to reduce the thickness 11 to that desired in the final magnetic toroid. Other methods may of course be employed in the reduction of the thickness 11, such as other known machining techniques, or reduction by chemical action. When the magnetic tube 10 is reduced to the thickness of magnetic material desired in the final magnetic core, the composite structure shown in Figure 1 is then sliced in directions substantially perpendicular to the major axis of the composite structure, for instance along lines 14, 15, 16 and 17. This slicing step may be effected by appropriate saw means such as a diamond saw having a high peripheral speed.

Referring now to Figure 2, it will be seen that the steps described previously effect a composite magnetic toroid exhibiting an external annular layer of magnetic material 18 which is supported on, and which is in close proximity to, an internal tube 19 of non-magnetic or of an insulating material. The structure shown in Figure 2 defines a central opening 20, inasmuch as the support 12 was tubular in configuration, and therefore one or more coils 21 may be wound on the structure in a direction substantially transverse to that of magnetic layer 18. Inasmuch as the winding or windings 21 are in fact disposed as shown, it is preferable to buff or otherwise round the edges of the composite structure such as 22 and 23 to remove any burrs or other sharp structures which might be present and which might cause short circuits between the windings 21 and the magnetic layer 18. In lieu of this practice, the exterior of the layer 18 and edges 22 and 23 of the composite structure may be coated with an insulating material to obviate such short circuits, or the windings 21 may be provided with relatively heavy insulation.

By employing the foregoing techniques, one may produce extremely small volume magnetic toroids in relatively large quantity and at relatively small cost. The technique permits the magnetic layer 18 to be reduced to any desired thickness down to and including a few mils, especially if the space factor of the composite core structure is not critical. Further, the method of the present invention permits the composite structure to be made to very close tolerances, and inasmuch as the supporting structure for the final composite core is included within the magnetic material from the very beginning of the fabrication steps, the said supporting structure, such as tube 12, supports the magnetic material not only in the final core but also throughout the various steps of grinding, or other reduction of magnetic material thickness, and slicing. This permits much greater ease in the handling of the several materials.

Referring now to Figure 3, it will be seen that in a modification of the present invention a plurality of magnetic tubes or toroids 24, 25, 26, etc. may be supported on and cemented to a single supporting tube 27 of an insulating or non-magnetic material such as has been described previously. The tubes 24, 25, 26, etc. may be of the same or varying cross dimension and may in fact have a cross dimension such as 28 which is initially the same as that desired in the final composite core structure. In this latter case the slicing step would merely slice the supporting tube 27 between the magnetic tubes or toroids and one need not slice the magnetic material 24, 25 or 26.

For true mass production techniques, combinations of the structures shown in Figures 1 and 3 may be employed, and one or more elongated tubes, such as 10, and/or one or more magnetic toroids such as 24, 25 and 26, may be mounted on a single supporting tube 27 whereby the several tubular sections of magnetic material may be selectively ground or otherwise reduced to the same or different thicknesses, and the structure may then be selectively sliced into toroids of the same or different widths.

Variations in the foregoing methods will readily sug-

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gest themselves to those skilled in the art. In particular, the various techniques for reducing the thickness of the magnetic materials may take a number of different forms and similarly the slicing steps may be effected by differing devices. Again, as mentioned previously, the magnetic tube 10 may be annealed (or fired, if a ferrite is employed) prior to insertion of the supporting tube 12, or if the said tube 12 is of a non-magnetic metal, or of an insulating material which will not be damaged by annealing temperatures, the structure may be assembled as shown in Figures 1 and/or 3 and the composite structure then can be annealed simultaneously. (Ferrites, having been fired, would of course require no annealing.) The actual conditions of temperature, pressure, atmosphere and time period of anneal will vary with the various materials employed, and these conditions are well known to those skilled in the art. It should be noted that if the composite structure of magnetic tube and supporting tube are to be annealed simultaneously, the materials should be so chosen that the supporting tube will not adversely affect the magnetic properties of the magnetic metal during the annealing step. The materials discussed previously for the several components of the composite structure satisfy this requirement.

Having thus described my invention, I claim:

1. The method of making a substantially toroidal magnetic structure which comprises the steps of inserting an elongated tube of non-magnetic material having appreciable structural strength into a tube of magnetic material whereby the internal surface of said magnetic tube is supported on the external surface of said non-magnetic tube attaching said tube of magnetic material to said tube of non-magnetic material, reducing the external diameter of said tube of magnetic material, while it is supported on said non-magnetic tube, to a final thickness of magnetic material normally having little structural strength per se, whereby the composite structural strength of said reduced diameter of magnetic tube supported on said non-magnetic tube is derived substantially entirely from said non-magnetic tube, and thereafter slicing said tube of non-magnetic material in a direction substantially transverse to the major axis thereof.

2. The method of claim 1 in which said reducing step comprises grinding the external peripheral surface of said tube of magnetic material.

3. The method of claim 1 including the step of winding an electrical conductor around the external surface of said reduced diameter magnetic material and the internal surface of said non-magnetic material in a direction substantially transverse to said magnetic material, subsequent to said slicing step.

4. The method of claim 1 including the step of coating said toroidal core slice with an insulating material subsequent to completion of said slicing step.

5. The method of making a substantially toroidal magnetic structure comprising the steps of inserting an elongated supporting tube of a non-magnetic metal into the central opening of a tube of magnetic metal having an initial external diameter substantially in excess of that desired in a final core, rigidly attaching said tube of magnetic metal to said non-magnetic supporting tube, reducing the annular cross dimension of said tube of magnetic metal, while it is supported by said non-magnetic tube to a relatively small volume of magnetic material carried by and supported on the external surface of said non-magnetic metal tube, and thereafter slicing said combined magnetic and non-magnetic metal tubes in a direction substantially transverse to the major axis thereof.

6. The method of claim 5 including the step of annealing the composite slices of magnetic and non-magnetic metals resulting from said slicing step.

7. The method of claim 5 including the step of disposing an insulating coating between said tubes of magnetic and non-magnetic metals during said inserting step.

8. The method of making a magnetic structure hav-

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ing a relatively small volume of magnetic material comprising the steps of inserting an elongated hollow supporting member of non-magnetic metal into the central opening of an elongated hollow magnetic tube, cementing the internal surface of said magnetic tube to the external surface of said supporting member by means of an adhesive exhibiting electrical insulation properties, reducing the external diameter of said magnetic tube while it is supported by and cemented to said non-magnetic metal supporting member, and thereafter slicing said composite magnetic tube and non-magnetic metal supporting member in a direction transverse to the direction of elongation thereof.

9. The method of making a substantially toroidal magnetic structure comprising the steps of inserting an elongated non-magnetic tubular supporting member into the central opening of a hollow ferrite tube, attaching the external surface of said non-magnetic tube to and in supporting relation to the internal surface of said ferrite tube, reducing the external diameter of said ferrite tube while it is supported by said non-magnetic tube to effect a final relatively small tubular volume of ferrite material supported by the external surface of said non-magnetic tubular member, and thereafter slicing said reduced volume ferrite tube in a direction transverse to the direction of elongation of said tubular supporting member.

10. A method for making magnetic core devices comprising the steps of inserting an elongated non-magnetic hollow supporting structure into a tube of magnetic material, rigidly attaching said magnetic tube to said non-magnetic structure, slicing the composite core composed of said magnetic material and supporting structure in a direction substantially transverse to the major axis of said supporting structure to form magnetic cores, and thereafter threading an electrical conductor through the hollow supporting structure on each of said composite cores to thereby form a winding on each of said cores whereby said core devices may be coupled to a magnetic system.

11. The method of making a substantially toroidal magnetic core having a substantially rectangular hysteresis characteristic, which comprises the steps of inserting an elongated tube of non-magnetic material into the central opening of a tube of magnetic material, attaching the internal surface of said magnetic tube to the external surface of said non-magnetic insulating tube by

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suitable adhesive means, slicing said attached tubes of magnetic and non-magnetic material in a direction substantially transverse to the major axis of said insulating tube thereby to provide a substantially toroidal core slice comprising a small substantially toroidal volume of magnetic material supported on the external surface of a substantially toroidal volume of non-magnetic material, and annealing said magnetic material so that said magnetic material exhibits a rectangular hysteresis characteristic.

12. The method of claim 11 wherein said annealing step is performed subsequent to said attaching step but prior to said slicing step.

13. The method of claim 11 wherein said annealing step is performed prior to the step of inserting said elongated tube of non-magnetic material into said tube of magnetic material.

14. The method of making a magnetic structure which comprises the steps of inserting an elongated supporting tube of non-magnetic material into the central openings of a plurality of tubes of magnetic material, rigidly attaching said magnetic tubes to said non-magnetic supporting tube in spaced relation, reducing the annular cross dimension of each of said tubes of magnetic material while they are so carried by said tube of non-magnetic material, said reducing step including the step of grinding the external peripheral surfaces of said tubes of magnetic material, said grinding step being such that different ones of said magnetic tubes are reduced to different annular cross dimensions, and thereafter slicing said supporting tube of non-magnetic material between said reduced dimension spaced tubes of magnetic material in a direction substantially transverse to the axes thereof.

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