Jan. 17, 1950 C. C. HORSTMAN ET AL 2,495,167

WOUND CORE

Filed May 19, 1945

Fig. 1.

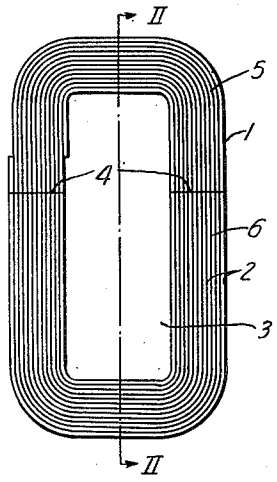


Fig. 2.

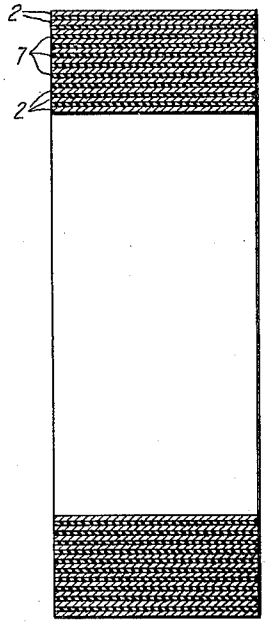


Fig. 3.

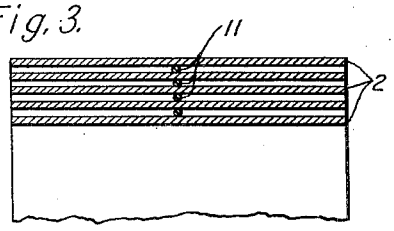
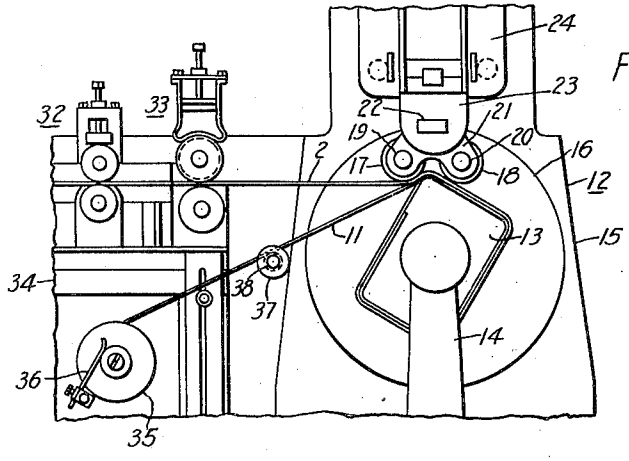


Fig. 4.



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WOUND CORE

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2 Claims. (Cl. 148—14)

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Our invention relates to electrical induction apparatus such as transformers and, particularly, to the core or magnetic circuit structure thereof.

Core structures of magnetic material have been developed in which the core loop is formed of a ribbon of magnetic sheet steel having preferred orientation of the grains of the material in the direction of the ribbon of steel, in which direction the lines of magnetic flux pass through the strip, thus resulting in a core having high permeability and low watts loss. The ribbon, or sheet of magnetic material, is wound on a mandrel or form of such shape as to give the desired window opening to the core structure and a predetermined thickness of the magnetic material. The core-loop sections so formed are then annealed to relieve strains in the material caused by the winding operation. The core may then be further processed and the parts assembled about the copper conducting coils of the electric circuit. This further processing may consist essentially of impregnating the core with an adhesive bonding material and baking to bond the laminations or consecutive turns of the strip tightly together, cutting the core into parts, working the butt-joint surfaces on opposite sides of the cut by grinding or machining, and treating the surfaces to remove short-circuiting burrs at the joint.

In forming this type of core, difficulties have arisen in keeping the tightness of the wound material at a desired value. If the steel strip forming the magnetic material of the wound core is too tight, it becomes difficult to properly impregnate the core with the bonding material, with the result that there may be some adjacent layers of the core that do not properly adhere to each other, so that, after the core is completed, it may split between these layers.

In the conventional practice of winding such cores, the tightness of winding is controlled by follower rolls that are maintained under a desired pressure upon the ribbon of magnetic sheet material as it is wound upon the mandrel, and by maintaining a desired tension on the ribbon as it is fed onto the roll. However, the steel strip of magnetic material that is wound to form the core has a basic stiffness depending upon its gauge or thickness, and there is a minimum required pressure that must be maintained upon this strip by the follower rolls, in order to properly form the core loop, and this minimum pressure increases with winding speed, in order to properly maintain the core shape. This minimum pressure necessary to establish the conformity of the steel strip around the mandrel, at an economical winding speed, is so high that the

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core is finished with extremely high space factor, that is, extremely high tightness of the consecutive turns of the sheet-steel ribbon, with a small amount of space between them. The innermost turns are under compressive stresses which are impossible to completely relieve with an economical strain anneal; hence, the core is likely to collapse after strain annealing, upon removal of the mandrel from the wound core structure. Also, the portion of the core which is not collapsed is wound so tightly that it is possible that too little space is left for satisfactory impregnation with the bonding compound. This results in many cores failing due to splitting apart between adjacent laminations. Those cores which do not fail due to splitting may give trouble in that accurate butt-joint surfaces are difficult to maintain because the residual stresses in the steel causes the core laminations to slip relative to each other, to some degree, so that the cut ends of the laminations do not maintain a uniform smooth surface, thus increasing the reluctance of the butt-joint. Also, the tight winding and consequent high pressure of each turn on the adjacent turn decreases the interlaminar resistance and causes an objectionable increase in eddy current loss of the core.

In accordance with the present invention, these difficulties are overcome by proper spacing of the consecutive turns of the wound core. The ribbon of magnetic sheet steel forming the core is wound simultaneously with a narrow strip of organic spacer material that is gasifiable during the annealing process, the strip of spacer material being positioned well inwardly from the edges of the strip or ribbon of magnetic sheet steel forming the core, such as approximately along the center line thereof. The organic material may be either a material that is decomposable at annealing temperatures leaving substantially no residue, or it may be a volatile material that volatilizes and disappears during the annealing process. In either case, the spacer material substantially disappears during the annealing process except for a small residue. Organic material such as cotton thread, flax, silk, superpolyamide strips, rayon cord, vinylidene chloride string or other fibrous material capable of decomposing, reacting with hydrogen to form gaseous products or volatilizing at annealing temperature may be used. Other substances, such as magnesium, which is an extremely volatile and reactive metal, which will react with hydrogen, nitrogen, or water vapor to form insulating residues, may be used.

Of the above-named organic materials, cellu-

losic materials, such as cotton thread, has been found satisfactory. A single strand of cotton thread may be used. A thread having a diameter between .0015 and .003 inch has been found to be satisfactory. This diameter compresses to a lesser figure under the pressure of the follower rolls during the winding process. The cores are usually formed with a rectangular window having straight sides and, when given a strain anneal after winding, a static load is applied to compress the core legs, maintaining them flat or parallel. The strain anneal takes place at a temperature above 500° C., preferably between 700° C. to 1000° C. in a reducing atmosphere preferably containing hydrogen. During this annealing operation, the carbon is removed from the cotton thread by decomposition into gases that are absorbed by a reducing atmosphere containing hydrogen so that no carburization of the steel strip occurs. The reducing atmosphere may be removed from the furnace by circulating it to further insure that no carburization of the steel strip occurs. This reducing atmosphere may consist largely of nitrogen and hydrogen. The removal of water and gaseous carbon products reduces the thread to a light streak of graphitic carbon which is of much less volume than the original thread. The volume of the thread substantially reduces or disappears. This reduction in volume is sufficient to provide looseness to enable full relief of compressive stresses within the core during strain annealing, yet the space factor is not decreased beyond reasonable limits. The residue of the cotton thread is very slight and does not interfere with the impregnation of bonding material between the adjacent layers of the steel strip.

We have tried other materials, such as a very thin layer of paper across the entire width of the ribbon of magnetic material, or some form of paint that will disappear during the annealing process, but the results were unsatisfactory, as the carbon residue over the entire surface of the strip interfered with proper impregnation of the core. It is necessary that the material used for spacing the successive layers of the core shall be narrow in width, as compared with the width of the steel, and positioned inwardly from the edges of the ribbon or strip of magnetic material forming the core, and preferably, substantially along the center of the strip to allow the desired impregnation between the successive layers from both sides of the wound core. If paper is used, it must be either in a very narrow strip, or in a wound thread form, so that its effect is similar to that of the cotton thread. The material used should generally be gasifiable in character so that, during the annealing process, it substantially disappears, except, perhaps, for a small residue, and this residue should be located well in from the edges of the steel strip so as not to interfere with the proper impregnation of the wound core.

The size of the thread or strip used should be varied for different core-loop structures, depending upon the size of the core loop and the gauge of the steel material used, to give the desired depth of spacing between successive layers. The thicker the steel-ribbon material used, the heavier will be the thread required to give the proper spacing. Also, the wider the steel strip and the larger the number of layers to be used, the heavier will be the thread required to properly space the successive layers.

It is an object of the invention to provide a wound core structure of the above-indicated character, in which the desired spacing is provided between the successive turns of the magnetic steel loop, to relieve undue strains in the material caused by winding the material too tightly, and to thus provide proper spacing between the turns required for proper impregnation of the core with bonding material after winding, and prevent adjacent core layers from adhering together as a result of the strain-anneal treatment.

More specifically, it is an object of the invention to provide a wound core, in which a ribbon of sheet steel and a strand of decomposable material are simultaneously wound, layer upon layer, providing a space between the several layers of the wound sheet, and in which the core is then annealed to remove strains in the steel caused by winding and to effect decomposition of the strand of material between the layers of the steel to reduce it to a negligible amount of material consisting of a light streak of graphite carbon and impregnating the wound steel core with a bonding material, and then baking the impregnated core loop to bond the laminations tightly together. The core loop thus formed may then be cut into parts that will readily fit about form-wound coils of electrical apparatus. The cut surfaces may be further worked as by grinding or otherwise treating the surfaces to remove short-circuiting burrs. The combustible material used may be thread, formed of cotton, flax, silk, or similar material, or narrow strips of paper.

The invention will be better understood by reference to the following description, having reference to the accompanying drawing, in which:

Figure 1 is a side elevational view of a conventionally wound core loop;

Fig. 2 is a sectional view through the line II—II of Fig. 1;

Fig. 3 is an enlarged sectional view of a portion of a core loop wound in accordance with the invention;

Fig. 4 is a side elevational view of a portion of the machine for winding the core.

Referring to the drawing, and particularly to Figure 1, a wound core loop 1 is illustrated, built in accordance with conventional design, formed by winding a strip 2 of magnetic sheet-steel ribbon upon a mandrel, forming a substantially rectangular window 3. After the strip material is wound, bonded, and given a strain anneal in accordance with conventional practice, it is cut along lines 4—4 to form two solid U-shaped portions 5 and 6. These U-shaped portions 5 and 6 may be separated and reassembled about preformed current-carrying windings in a well-known manner.

Fig. 2 is a sectional view, somewhat enlarged, to better show the layers of insulating bonding material 7 existing between layers of the sheet-steel ribbon 2, this insulating material being the bonding material above-referred to, with which the core is impregnated by applying the material under pressure, after winding and annealing. Its use results in solidly bonding the adjacent layers of sheet steel together to form a solid core structure.

In Fig. 3, several layers of the sheet-steel ribbon 2 are shown wound with successive layers of threads 11 between them, as above described, the thread being positioned substantially along the middle of the width of the steel strip 2. Although the threads 11 are shown in Fig. 3 as substantially round, it will be appreciated that,

under the pressure of the process of rolling, they will be considerably flattened to perhaps one-third of their diameter when freely suspended without pressure being applied. Even though the thread is shown positioned essentially along the middle of the width of the strip it may be varied alternately on either side of the center line of the strip during winding. This will result in a more even build up of layers and eliminate any "ridging" due to each layer of thread being essentially on top of the one beneath it.

Referring to Fig. 4, a machine 12 is illustrated for winding the core loop and shows a mandrel 13 in position for winding the strip 2 simultaneously with the thread 11 to provide layers of the thread between successive layers of the steel. The machine 12 may be substantially similar to that shown in United States Patent No. 2,264,800, issued to C. C. Horstman, John H. Bramble and Fred R. Miller on December 2, 1941, and assigned to the same assignee as this invention.

The mandrel 13 is supported in position for winding partly by the frame member 14 and partly from a shaft (not shown) carried by the machine frame 15 which carries the winding head 16 upon which the mandrel 13 is directly mounted. Follower rolls 17 and 18 are mounted by pins 19 and 20 on a supporting member 21 which, in turn, is pivotally mounted at 22 to a carriage 23 that is slidably mounted within a bracket frame structure 24. Means (not shown) is provided for applying a downward force to the movable carriage 23 so as to apply pressure through the follower rolls 17 and 18 against the strip 2, while it is being wound upon the mandrel 13. Two sets of braked rolls 32 and 33 are provided on a suitable frame 34, partly for flattening and removing any burrs that may exist on the outer edges of the sheet steel and partly for applying a braked pressure to maintain the ribbon of sheet steel 2 under a desired tension as it is drawn by the rotating mandrel to be wound, layer upon layer. A suitable reel 35 is provided from which is supplied the thread 11, the reel being shown as having a friction brake 36 for resisting its rotation so as to maintain a slight tension on the thread 11. A guide wheel 37 is provided having a deep groove 38 and suitably mounted in a position to guide the thread 11 so that it will be wound substantially centrally or alternately from side to side of the center line of the strip of steel, as shown in Fig. 3. Any other suitable means for so guiding the thread or properly locating it may be used.

It will be understood by those skilled in the art that modifications may be made in the details of the structure illustrated and described, and in the method of constructing the core without departing from the spirit of our invention and we do not wish to be limited otherwise than by the scope of the attached claims.

We claim as our invention:

1. In the method of making a magnetic core structure, the steps comprising simultaneously winding a ribbon of magnetic sheet steel material which is subject to carburization layer upon layer around a shaping form to provide a closed magnetic circuit loop and a strip of decomposable organic spacing material that is very much narrower than the ribbon of magnetic sheet steel material inwardly from the edges of the ribbon of magnetic sheet steel material for spacing the successive layers of the ribbon, heating the wound core loop at a temperature sufficiently high to strain anneal the wound core loop and to decompose the decomposable organic spacing material in a reducing and decarburizing atmosphere containing hydrogen to prevent carburization of the magnetic sheet steel material by removing the gaseous products of decomposition, impregnating the spaces between the successive layers of the ribbon of magnetic sheet steel material with bonding material and baking to bond the several layers of the magnetic material solidly together.

2. In the method of making a magnetic core structure, the steps comprising simultaneously winding a ribbon of magnetic sheet steel material which is subject to carburization layer upon layer around a shaping form to provide a closed magnetic circuit loop and a single strand of decomposable thread between the layers inwardly from the edges of the ribbon of magnetic material for spacing the successive layers of the ribbon, heating the wound core loop at a temperature sufficiently high to strain anneal the wound core loop and to decompose the decomposable thread in a reducing and decarburizing atmosphere containing hydrogen to prevent carburization of the magnetic sheet steel material by removing the gaseous products of decomposition, impregnating the spaces established by the strand of thread between the successive layers of the ribbon of magnetic material with bonding material and baking to bond the several layers of the magnetic material solidly together.

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