Aug. 2, 1960 C. W. MOODY ET AL 2,947,065

METHOD OF MAKING A JOINT IN A WOUND MAGNETIC CORE

Filed Feb. 17, 1953

Fig. 1.

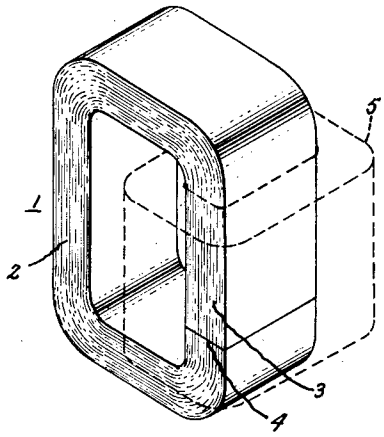


Fig. 2.

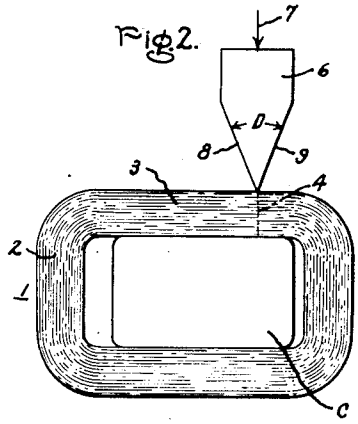


Fig. 3.

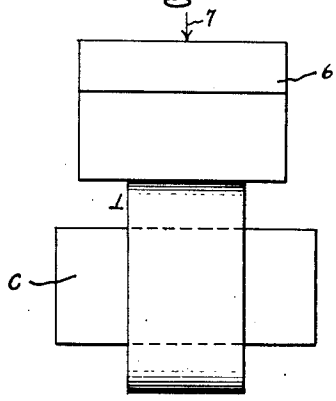


Fig. 4.

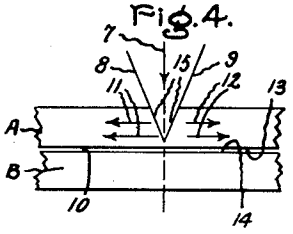


Fig. 5.

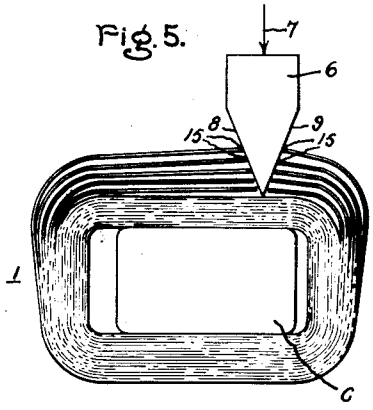
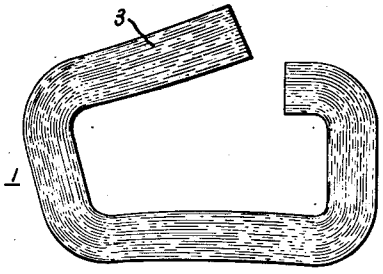


Fig. 6.



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METHOD OF MAKING A JOINT IN A WOUND MAGNETIC CORE

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11 Claims. (Cl. 29—155.57)

This invention relates to wound magnetic cores for electric induction apparatus and more particularly to a new method of making a joint in such cores.

Since the development of magnetic strip material, such as high reduction, cold rolled silicon steel, which has highly favorable magnetic properties in the direction of rolling, i.e., in the lengthwise direction of the strip, wound cores have increased in importance because they inherently make good utilization of those properties by permitting the magnetic flux to travel always in the favorable direction especially at the corners. However, there has always been a problem in linking such a core with a conductive winding so as to form an operative induction apparatus.

One approach to the above problem is to provide the core with a joint or joints whereby the portions of the core adjacent the joints may be separated so as to permit pre-wound conductive windings to be assembled about the legs of the core.

Heretofore these joints have been formed by cutting through the assembled laminations of the core by means of a saw, a milling cutter, or a thin abrasive wheel. Such cutting apparatus is often rather complex and costly, and its use results in surfaces which are highly burred. These burrs must be removed by an additional working step such as etching or lapping in order to prevent the laminations from being short circuited by the burrs. This additional step involves considerable expense and labor and, thus, it would be highly desirable if surfaces essentially free of burrs could be obtained from the original cutting operation.

In accordance with this invention, a cutting method is employed which results in a joint which is essentially free of burrs and which makes it possible to use simple and inexpensive cutting apparatus. More particularly, the laminations of the assembled core are severed by a pinch-cutting operation, that is, by pressing a wedge-shaped blade therethrough by appropriate force applied to the blade. This relatively simple cutting operation is made practical by employing a preliminary step which involves impregnating the assembled core with a lubricating medium which acts as a separating and supporting film between the laminations during the cutting operation of the core. This film not only permits the cutting blade to rapidly penetrate the assembled laminations but also permits the penetrated laminations to expansively yield in such a manner that the surfaces adjacent the cut are essentially free of burrs.

An object of this invention is to provide a new and improved method of making a joint in a magnetic core for electromagnetic induction apparatus.

Another object of this invention is to form a joint for a magnetic core by a new and improved method which employs relatively simple cutting apparatus and yields a cut which is essentially free of burrs.

The invention will be better understood by considering the following description taken in connection with the

accompanying drawing and its scope will be pointed out in the appended claims.

In the drawing, Fig. 1 is a perspective view of electric induction apparatus embodying a core made in accordance with the invention, which core is normally provided with a winding which is indicated in phantom; Fig. 2 shows a step in the method of making the core; Fig. 3 is a side view of the core and apparatus shown in Fig. 2; Figs. 4 and 5 are views illustrating the action of the cutting blade during the cutting operation; and Fig. 6 shows how after the cutting operation has been completed the core may be flexed for the purpose of linking it with a conductive winding.

Referring now to the drawing and more particularly to Fig. 1, there is shown, by way of example, a generally rectangular shaped wound core **1** consisting of a plurality of radially nested layers **2** of magnetic strip material. This core has a generally straight winding leg **3** and a butt joint **4**, which is within the lateral confines of the winding leg **3**. As shown in phantom, conductive windings or a winding **5** is ordinarily mounted on the winding leg.

The core is preferably wound with a predetermined space factor between the superposed laminations or layers **2**, in the usual manner from a strip of conventionally treated magnetic material. The wound core is then annealed in the usual manner, after which it is placed in a bath of lubricating material, which during the subsequent cutting operation will serve as a supporting and separating agent for the laminations **2** in a novel manner to be described in greater detail hereinafter. The core is allowed to soak in this bath until the minute spaces between adjacent laminations become impregnated with the lubricating material and a thin film of this material separates juxtaposed pairs of lamination surfaces.

For the purposes of our invention, this material of the bath may be an oil having a relatively high viscosity above 1200 centipoises at 25° C. Since this relatively high viscosity would prevent thorough and proper impregnation of the core at room temperature, we have found that effective impregnation may be obtained by elevating the temperature of the bath to such a level as would lower the viscosity sufficiently to permit the material to flow into the minute spaces between the laminations. It is possible to use lower viscosity oils, but if such oils are used, then they should be refrigerated after the impregnation step so as to increase their viscosity to above 1200 centipoises at the time of the cutting operation.

Certain solids, such as the cyclic organic compounds of naphthalene, camphene, or camphor, which can be melted, as by heat, for the purposes of impregnation and then solidified before the cutting operation, also serve as effective lubricating materials. These latter materials are especially desirable where a plastic bonding process is subsequently relied upon to complete the final core assembly. The reason for this desirability is that these latter materials may be easily and completely removed from the core by vaporization, thus leaving the core essentially free of any contamination residue which would interfere with the aforesaid subsequent plastic bonding process. Certain uncured plastic bonding agents, while in the liquid state, may also be used for a lubricant provided their viscosity at the time of cutting approximates the value specified for oil. Examples of such materials are the epoxy resins, such as described on page 438 of the 1952 Modern Plastics Encyclopedia and Engineer's Handbook, published by the Plastics Catalogue Corp., New York, N.Y. It is essential that the cutting operation, which follows, take place before the plastic bonding material is cured. By using such uncured plastic materials it is possible to obtain the properties of a lubricant and a bonding agent in a single impregnant. Thus, it is unnecessary to remove the lubricating material preparatory to the plastic

bonding process; that is, the lubricant itself is cured to provide the final bonding agent.

As an additional example, even water has been found to be effective as a lubricating material providing it is frozen after the impregnation process, thereby producing a film of ice between juxtaposed surfaces of the laminations. This ice film may be formed by suitably refrigerating the core assembly after it has been impregnated by the water.

Although we have disclosed forming the lubricating film on the lamination surfaces after the core is wound, in some applications it is desirable to form this film prior to the winding step.

As is illustrated by Figs. 2 and 3, after the impregnation step the core is placed about an anvil C and is cut at 4 by the action of a wedge-shaped cutting blade 6 formed of a high carbon tool steel hardened to at least Rockwell C 60. This blade 6 is forced through the laminations 2 by means of an essentially constant force indicated at 7 and applied by suitable means such as a hydraulic press (not shown). It has been found that an optimum angular relationship for the cutting surfaces of the blade is a 45 degree included angle D between the wedge surfaces 8 and 9. The tip of the blade may be blunted to about a .001 inch radius. This angular relationship is critical within plus or minus 10 degrees because a smaller angle radically shortens the blade life and a larger angle materially impairs the effectiveness of the cutting action for reasons to be described in greater detail hereinafter.

The cutting method of this invention is not practical unless the spaces between the laminations are thoroughly impregnated with the lubricating material previously described and shown in a somewhat exaggerated form at 10 in Fig. 4. As illustrated in Fig. 4, the action of the wedge-shaped blade as it penetrates each lamination, one being indicated at A, tends to force the portions of the lamination which are disposed on opposite sides of the line of force 7 to yield in opposite directions 11, 12 generally normal to the line of force 7. This yielding action coupled with the expansive forces due to the divergent blade surfaces 8, 9, subjects the lamination to rather high stresses acting in the directions 11, 12. Our tests indicate that at, or slightly before, the instant that the blade completely penetrates lamination A, these stresses are effective to suddenly expand the lamination and to rapidly separate the surfaces 15 of the cut from the blade surfaces 8, 9. This sudden expansion or separation leaves some very minor irregularities at the extreme bottom of surfaces 15, but these irregularities are insignificant from the standpoint of harmful burr formation because, with our invention, it appears that the sudden expansion is so rapid that the blade surfaces are not given an opportunity to bend over and elongate these minor irregularities, thus converting them into burrs of the type which cause short circuits between the laminations. The key to this rapid expansion of opposed portions of the exemplary lamination A lies in the thin film of lubricating medium 10 which separates lamination A from its adjacent lamination B. To explain further, these adjacent laminations A and B have juxtaposed surfaces 13 and 14, each of which contains minute irregularities. Unless these irregular surfaces 13 and 14 are maintained in a spaced condition, undesirable frictional contact between them would be established, hence creating a strong frictional drag acting in opposition to the previously described expansive forces acting at 11, 12. This frictional drag would retard the expansive separation of opposed surfaces 15 of the cut to the extent that those above described irregularities at the bottom of surfaces 15 would be bent over and elongated into harmful short circuiting burrs. As has been stated, according to our invention, the surfaces 13 and 14 are maintained in a spaced condition by the thin film of lubricating medium 10, thus minimizing the inter-surface frictional drag and its accompanying undesirable effects.

It has been found that not only would the above described frictional drag result in short circuit producing burrs, but this drag would also render the cutting operation extremely difficult and would radically shorten the life of the blade 6. Because of the resulting inability of the laminations to rapidly yield in a transverse direction, the laminations would tend to seize and become, in effect, welded together by the high pressure of the blade, and the laminated core would resist the cutting operation almost to the same extent as would a solid bar of silicon steel.

As previously noted, the angular relationship D between surface 8—9 should be between 35 and 55 degrees in order that optimum cutting action result. If this angular relationship is less than 35 degrees, the blade life is radically shortened because of the resulting weakness of the blade to transverse forces. If the angular relationship is greater than 55 degrees, then during the cutting action the component of force acting normal to the surface 13 of lamination A, i.e., along line 7, is so large compared to the transverse components acting along lines 11, 12 that the frictional drag opposing expansive yielding action becomes excessive. Such excessive frictional drag results in burr formation, shortened blade life, and the other cutting difficulties referred to above. Another factor which controls the maximum permissible included angle is that the greater is the component of force acting along line 7, the greater is the tendency of the lubricating medium to have its effectiveness impaired by being forced out from between the laminations.

As each lamination is severed by the blade 6, surfaces 15 adjacent the cut are forced apart by the wedge surfaces 8 and 9 of the blade, and the severed laminations are forced to assume the generally expanded position shown in Fig. 5. The lubricating properties of the impregnant further assure that a minimum of resistance to this expansive movement is provided.

To insure that the radially innermost lamination of the core is completely penetrated by the blade 6, we may interpose between the core and the top surface of the anvil a pair of steel shims, one on each side of the plane of the cut. It is obvious that the blade mount (not shown) should be provided with suitable stops for preventing blade contact with the anvil.

After all of the laminations 2 have been completely severed by the cutting action, the core 1 may be flexed in the usual manner, as shown in Fig. 6, so that the winding 5 may be slipped about the leg 3 so as to be mechanically and inductively linked thereto. The laminations adjacent the joint 4 may be held together in abutting relationship in the final core form by any well known plastic bonding process or mechanical clamping means, or both, as is conventional in the art.

Referring to the plastic bonding process, if the lubricant used during the cutting was the plastic bonding agent in an uncured liquid form, as was previously described, then the lubicant itself may be suitably cured or hardened to form the final plastic bond. If other types of lubricant were used, then it would be necessary to remove the lubricant after the cutting operation so as to prevent interference with the bonding process. In most cases, this removal can be accomplished by vaporizing the lubricant, as by oven-baking or a similar heating process. Certain materials may be removed simply by drainage providing conditions are favorable.

It will be apparent from the preceding description of our invention that substantially none of the material of the core was removed during the cutting operation. This is a decided advantage in the case of a single-jointed core, since it is unnecessary to subject the core of our invention to any significant stresses in order to form the final joint. Where core material is removed in the single-jointed type of core, as by the conventional sawing or abrasive cutting operation, it is necessary that the core be compressed or contracted in order to produce abutting

lamination surfaces at the finished joint. Such a compression sets up undesirable stresses in the laminations which result in a material increase in the core losses.

While we have shown our pinch-cutting method as being applied to form the joint of a single-jointed core, it is, of course, obvious that such method could be used to form any desired number of joints in the core. Similarly, it is readily apparent that our pinch-cutting method could equally well be used for cutting through a laminated assembly of the type shown in Fig. 13 of the Vienneau Patent No. 2,305,649, assigned to the assignee of the present application.

While there has been shown and described a particular embodiment of the invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention, and that it is intended by the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A method of making a joint in a magnetic core for induction apparatus comprising the steps of spirally winding a metallic strip into an assembly comprising turn laminations of said strip which are radially nested and superposed with respect to each other in spaced relationship, impregnating the assembly with a lubricating material so that a film of lubricant is formed between juxtaposed surfaces of said laminations, and then pinch-cutting the laminations by forcing a wedge-shaped blade through the assembled laminations thereby forcing each of the laminations as it is penetrated by said blade to expansively yield along its lubricated surface in a direction transverse to the line upon which force is applied to the blade.

2. A method of making a joint in a magnetic core for induction apparatus comprising the steps of spirally winding a metallic strip into an assembly comprising turn laminations of said strip which are radially nested and superposed with respect to each other in spaced relationship, impregnating the assembly with a lubricating material so that a film of lubricant is formed between juxtaposed surfaces of said laminations, and then pinch-cutting the assembled laminations by subjecting each successive lamination to an operation which comprises forming therein with a wedge-shaped blade a wedge-shaped impression defined by opposed surfaces extending substantially throughout the entire thickness of the lamination and then forcing said wedge-shaped blade through the lamination to force the lamination to expansively yield along its lubricated surface to cause said opposed surfaces to rapidly separate so as to minimize burr formation at said opposed surfaces.

3. The method of claim 2 being further characterized by said lubricating material being a hydrocarbon composition having a viscosity at 25° C. of above 1200 centipoises.

4. The method of claim 2 being further characterized by said lubricating material having a viscosity of above 1200 centipoises at the time of the cutting operation.

5. The method of claim 2 being further characterized by said lubricating material being a cyclic organic compound selected from the group consisting of naphthalene, camphene and camphor.

6. The method of claim 2 being further characterized by said lubricating material being an uncured plastic in liquid form at the time of the cutting operation, said plastic being adapted when cured to act as a bonding agent between the surfaces of the laminations.

7. A method of making a joint in a magnetic core for induction apparatus comprising the steps of spirally winding a metallic strip into an assembly comprising turn laminations of said strip which are radially nested and superposed with respect to each other in spaced relationship, impregnating the assembly with a lubricating material so that a film of lubricating material is formed between juxtaposed surfaces of said laminations, and then pinch-cutting the assembled laminations by subjecting each successive lamination to an operation which comprises forming therein with a wedge-shaped blade a wedge-shaped impression defined by opposed intersecting surfaces diverging at an included angle of between 35 and 55 degrees and extending substantially throughout the entire thickness of the lamination, and then forcing said wedge-shaped blade through the lamination to force the lamination to expansively yield along its lubricated surface to cause said opposed surfaces to rapidly separate so as to minimize burr formation at said opposed surfaces.

8. A method of making a joint in a magnetic core for induction apparatus comprising the steps of spirally winding a metallic strip into an assembly comprising turn laminations of said strip which are radially nested and superposed with respect to each other in spaced relationship forming a film of lubricating material between juxtaposed surfaces of said laminations by impregnating the assembly with a lubricating material at a given temperature and subsequently lowering the temperature of said lubricating material after said assembly is impregnated, and then pinch-cutting the assembled laminations by subjecting each successive lamination to an operation which comprises forming therein with a wedge-shaped blade a wedge-shaped impression defined by opposed surfaces extending substantially throughout the entire thickness of the lamination and then forcing said wedge-shaped blade through the lamination to force the lamination to expansively yield along its lubricated surface to cause said opposed surfaces to rapidly separate so as to minimize burr formation at said opposed surfaces.

9. The method of claim 8 being further characterized by said impregnant being water and said film being ice.

10. A method of making a joint in a magnetic core for induction apparatus comprising the steps of spirally winding a metallic strip into an assembly comprising turn laminations of said strip which are radially nested and superposed with respect to each other in spaced relationship impregnating the assembly with a lubricating material so that a film of lubricating material is formed between juxtaposed surfaces of said laminations, and then pinch-cutting the assembled laminations by subjecting each successive lamination to an operation which comprises forming therein with a wedge-shaped blade a wedge-shaped impression defined by opposed intersecting surfaces diverging at an included angle of between 35 and 55 degrees and extending substantially throughout the entire thickness of the lamination, said opposed surfaces intersecting along a line substantially parallel to said juxtaposed surfaces of said laminations, and then forcing said wedge-shaped blade through the lamination to force the lamination to expansively yield along its lubricated surface to cause said opposed surfaces to rapidly separate so as to minimize burr formation at said opposed surfaces.

11. A method of making a joint in a strip wound magnetic core which comprises an assembly of a plurality of radially nested and superposed turn laminations, said method comprising providing the adjacent surfaces of said laminations with a film of lubricating material, and then pinch-cutting the laminations by forcing a wedge-shaped blade through the assembled laminations thereby forcing each of the laminations as it is penetrated by said blade to expansively yield along its film of lubricating material in a direction transverse to the line upon which force is applied to the blade.

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