Oct. 5, 1943. J. C. GRANFIELD 2,330,824

METHOD OF MAKING MAGNETIC CORES

Original Filed Jan. 28, 1941

Fig. 1.

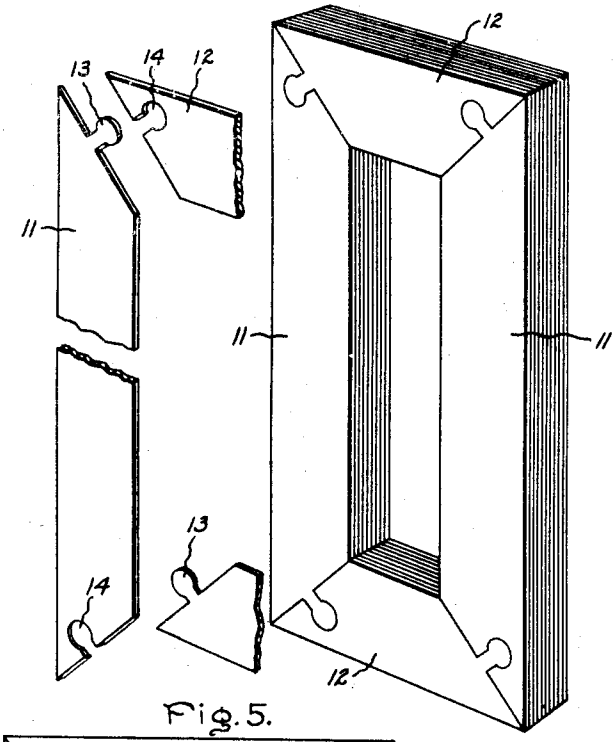


Fig. 2.

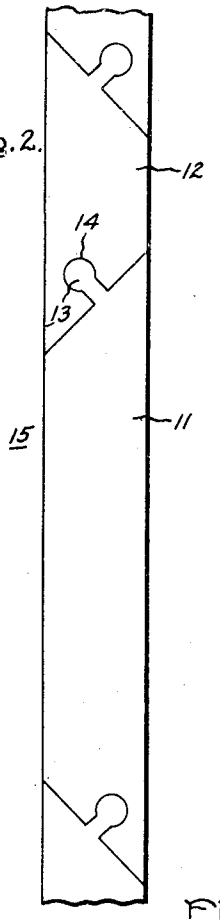


Fig. 5.

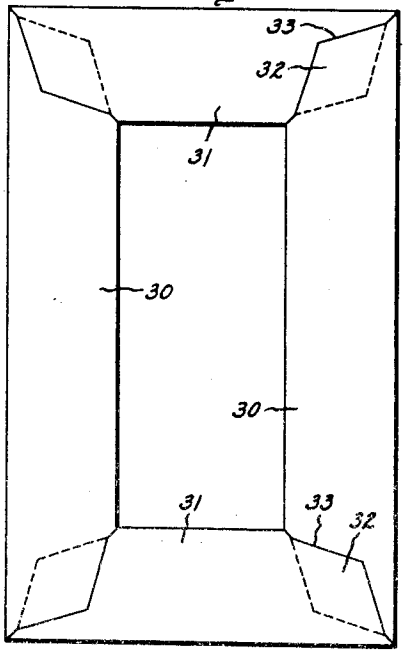


Fig. 6.

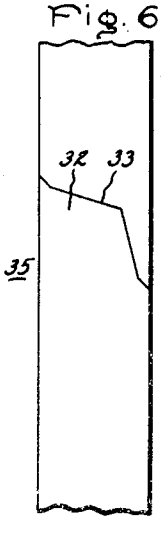


Fig. 3.

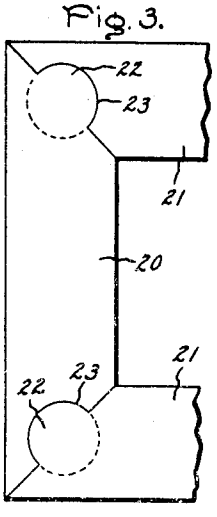
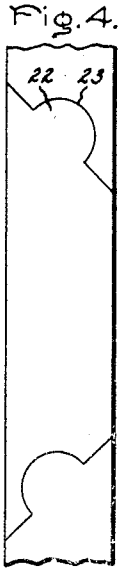


Fig. 4.



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UNITED STATES PATENT OFFICE

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METHOD OF MAKING MAGNETIC CORES

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Original application January 28, 1941, Serial No. 376,304. Divided and this application November 25, 1941, Serial No. 420,425

3 Claims. (Cl. 29—155.5)

This invention relates to improvements in laminated magnetic core structures for electrical induction apparatus such as transformers and reactors, and to methods for making such improved core structures.

This application is a division of my copending application S. N. 376,304, filed January 28, 1941.

In the usual construction for magnetic cores, the laminations are cut or punched from relatively large stock sheets which are produced by a rolling process from bars or billets of a suitable magnetic material such as silicon steel or a magnetic nickel iron alloy. The rolling process produces a grain structure in the sheets which may extend in the direction in which the sheets have been rolled. The path of least magnetic resistance of such material is generally in the direction that the sheets have been rolled, though in certain types of steel the most favorable magnetic direction, in so far as low flux losses are concerned, is at some angle with respect to the rolling direction. It has been found that optimum results for magnetic cores are obtained if the laminations are so cut from the sheets of magnetic material that the core flux path is parallel with the path of least magnetic resistance thereof.

One common form of a magnetic core consists of a stack of L-shaped punchings but it is obvious that such shapes cannot be punched as a single piece from standard stock in such a manner that the most favorable magnetic direction extends parallel with the flux path in both parts of the punching. This is due to the fact that the grain extends in the same direction throughout all parts of the stock sheet while the two parts of an L-shaped punching are at right angles to each other. Another common form of core consists of rectangular laminations stacked at right angles with respect to each other. While the most favorable magnetic direction in this type of core may be made parallel with the direction of the flux path throughout the central portion of the laminations, the core flux must cut crosswise of the most favorable direction at the ends of the laminations in traversing from one core leg to the next. Due to this crosswise flow of flux at the corners of the core, relatively high losses occur at these points.

It is therefore a general object of the present invention to provide a new and improved magnetic core comprising a stack of punched laminations which is characterized by low losses throughout the magnetic circuit.

More specifically, it is an object of the invention to provide a new and improved core in which the laminations are so cut from the metal stock that when fitted together into a unit, the core flux may flow in the most favorable magnetic direction of the laminations substantially completely throughout the magnetic circuit.

It is a further object of the invention to provide a new and improved method of making low loss magnetic cores from metal stock with no waste of material.

Further objects and advantages of the invention will appear from the following description taken in connection with the accompanying drawing, while the features of novelty will be pointed out with greater particularity in the appended claims.

In the drawing, Fig. 1 is a view in perspective of a magnetic core employing my improved laminations; Fig. 2 is a view illustrating my improved method by which the laminations for the core of Fig. 1 are produced; Fig. 3 is a plan view of a portion of a magnetic core illustrating a further modification of the core illustrated in Fig. 1; Fig. 4 is a view illustrating the manner in which the laminations for the core of Fig. 3 are produced according to my improved method; Fig. 5 is a plan view of a magnetic core illustrating a still further modification of the core shown in Fig. 1; and Fig. 6 is a view illustrating the method in which the laminations for a core such as shown in Fig. 5 are produced.

Referring now to Fig. 1 of the drawing, a magnetic core is shown having legs made up of stacks of laminations 11 and yokes made up of stacks of laminations 12. The adjacent stacks are angularly arranged with respect to each other and in the case of the rectangular core as shown, the stacks are arranged at right angles. The ends of the stacks are cut at an angle which is less than 90 degrees and substantially equal to one-half of the angle between adjacent stacks whereby the stacks may be fitted together in an end to end relation. In other words, the diagonally cut end of each stack is substantially covered by the similarly or cooperatively cut end of the adjacent stack. It is not essential that the ends of each lamination of each stack be cut along a straight line or even along similar lines, but it is preferred, however, that, in the case of a rectangular core as shown and having substantially the same cross section in each stack, the ends of the lines along which the lamination ends are cut terminate on a line which is at 45 degrees with respect to the side edges of the laminations. In any case, the end edges of the adjacent lami-

nations when the core is assembled butt together in a parallel relation to form what will be termed a mitered joint between laminations of each layer and, hence, between the adjacent ends of each pair of angularly arranged stacks.

In order that the reluctance of the magnetic circuit be held to a minimum, the butt joints between the lamination stacks must be made tight, and preferably means be provided for maintaining the tightness of the joints throughout normal usage of the device. Clamping means may be used for holding the leg and yoke portions tightly against each other but such clamps, if solely relied upon for this purpose, would in all probability need to be tightened to such an extent that internal strains may be produced thereby in the laminations which in turn would adversely affect the magnetic properties of the metal.

In the modification illustrated in Fig. 1, the ends of the laminations are so shaped and fitted together that a tight joint is assured between the leg and yoke stacks without requiring tight clamping means. The laminations 11 and 12 are each provided at one end with a dovetail projection 13 extending perpendicularly from the diagonal edge and an opening or indentation 14 in the opposite end for cooperatively receiving a similar dovetail projection of the adjacent lamination. The projections 13 and the cooperating openings 14 are so matched that when the laminations are fitted together in the assembly of the core, there will be no appreciable gap between the ends of adjacent laminations. It will be obvious that after the core has been assembled, subsequent separation of the legs and yokes of the core will be substantially precluded by virtue of the interlocked portions.

In assembling the lamination layers it is preferred that adjacent layers be oppositely arranged so that the projections at the ends of the laminations of adjacent layers will extend in opposite directions. With the layers so arranged, edgewise shifting of the laminations of one layer with respect to each other will be precluded. Only a relatively light clamping means need be provided for holding the lamination layers together and such clamping means need not be drawn so tight as to set up any appreciable strains in the metal of the laminations.

The laminations 11 and 12 are so cut from the stock sheets of metal that the most favorable magnetic direction of the metal will run lengthwise of the laminations. When the laminations are assembled as illustrated, due to the mitered joints at the corners of the core, the core flux may flow through the leg and yoke portions substantially continuously in the most favorable magnetic direction of the metal throughout the magnetic circuit and substantially without cutting crosswise of such direction at any point. A highly efficient magnetic circuit is thus provided.

The laminations are formed from a strip of magnetic material in a manner illustrated in Fig. 2. The strips of magnetic material such as silicon steel or a magnetic nickel iron alloy are preferably produced by the high reduction cold rolled process from bars or billets so that the strips have a granular structure, the grain extending longitudinally of the strips and parallel to their side edges and having the most favorable magnetic direction substantially parallel with the grain direction. The strips may be of any desired width and of indefinite length. The strips are preferably of the exact width of the laminations to be used in the magnetic core.

The laminations are cut or punched from such a strip 15 by any suitable means (not shown) such as a suitable set of dies. The strip is cut crosswise at recurrent intervals, depending upon the length of the laminations to be formed, and at an angle substantially equal to one-half of the angle which is to be formed by two adjacent lamination stacks. The direction of the cut across the strip is alternated, or in the case of laminations for a rectangular core when each cut will be along a base line at 45 degrees to the strip edge, the alternate cuts will be displaced by 90 degrees from the others. In order that the projection provided on the diagonal end of one lamination will register accurately with the opening thus formed in the end of the next adjacent lamination when placed at right angles with respect thereto, the projection should extend from the exact center of the diagonal and be exactly symmetrical on both sides of a perpendicular erected from the center of the diagonal. It will be obvious that the leg laminations 11 may all be punched from one strip and the yoke laminations 12 from another, or they may be punched alternately from the same strip as illustrated in Fig. 2. By either method of punching the laminations, there will be no waste of material.

The particular configuration for the dovetail joints between the leg and yoke laminations is immaterial, it being important only that it be so designed that a minimum amount of metal extend into the flux path with the grain thereof at an angle other than that of the core flux path.

In producing the cores by this method it is preferred to first punch out the laminations in the manner described and then form desired shapes such as L, U, or rectangular by interlocking component parts and then annealing the assembled shape. By assembling the shapes first and then annealing them with a proper heat treatment to remove strains produced in the metal by the punching operation, the interlocked parts will enlarge slightly to further tighten the joint and thereby practically eliminate the gap effect.

In certain types of cores, it may not be necessary to interlock the laminations in order to insure a sufficiently tight joint between the diagonally cut ends. The modifications of core structures illustrated in Figs. 3 to 6, inclusive, are particularly suitable for smaller sized cores, or in cores built up from relatively thin laminations. The magnetic core of Fig. 3 comprises stacks of laminations forming legs 20 and yokes 21 the laminations for which are so punched from stock sheets of magnetic material that the most favorable magnetic direction thereof extends substantially parallel with the flux path through the laminations, as in the previously described modification. The opposite ends of the leg and yoke laminations are cut diagonally so that the right angularly arranged laminations of each layer fit together at the corners with mitered joints as in the core described above. In this modification, however, the diagonal edge at one end of each of the laminations is provided with a non-interlocking projection 22 while the opposite diagonal edge is provided with a corresponding notch 23 for cooperatively receiving the projection of an adjacent right angularly arranged lamination. As illustrated, the projection and

the cooperating notch may be of a semi-circular configuration, although it is to be understood that the projection and notch may be of any other suitable shape.

In the assembly of the core of this modification, the laminations of each layer are fitted closely together so that there will be a minimum of space between adjacent ends. The adjacent lamination layers are also oppositely arranged so that the projections of the adjacent lamination layers will extend in opposite directions, as is indicated by the dotted lines in Fig. 3. With the laminations assembled in this manner the projections of each lamination will overlap with portions of right angularly extending laminations of adjacent layers on the opposite sides thereof. The lamination layers may then be compressed by any suitable clamping means (not shown) which are so applied as not to set up any appreciable internal strains within the metal of the laminations which might adversely affect the magnetic properties thereof. Due to the frictional resistance between the overlapping portions of the adjacent lamination layers, separation of the leg and yoke portions of the core at the joints will be substantially precluded.

While the laminations for the leg and yoke portions of the core may be cut from stock sheets of magnetic material of any dimension with the most favorable magnetic direction extending parallel to the path of the core flux through the laminations, it is preferred that the laminations be punched from a relatively long narrow strip **25** or one having the same width as the laminations, as shown in Fig. 4. The manner of punching the laminations from the strip is similar to that described above in connection with Fig. 2. In order that the laminations will fit properly together when arranged at right angles with respect to each other, it will be necessary that the diagonal edge be at an angle of 45 degrees with respect to the side edges of the strip and that the projection and the notch provided on the opposite diagonal edges of each lamination be symmetrical on the opposite sides of a perpendicular erected from the center of the diagonal. With the ends of the laminations so punched, it will be obvious that the parts may be fitted accurately together with no appreciable gap between the adjacent end edges.

In Fig. 5 is illustrated a further modification of the invention in which a magnetic core is shown comprising leg portions **30** and yoke portions **31** which are also fitted together with generally diagonally mitered corner joints but of a slightly different configuration than those previously described. In this modification one end of each of the laminations is provided with a triangular projection **32** which extends from a true diagonal line while the opposite end is provided with a corresponding notch **33** for cooperatively receiving a similar projection from a lamination extending at right angles with respect thereto. The base of the triangular projecting portion of each lamination, that is, along the line of the diagonal, is preferably just slightly narrower than the length of the diagonal, while the height of the triangle is of the order of one-fourth of the width of the base. Thus, it will be observed that the width of each lamination increases progressively from zero at the outermost end to maximum width at the inner corners of the diagonal edges. The rate of progressive increase of width varies from minimum to maximum along the end edge of the laminations depending upon the particular angle of the two sides of the triangular projection and recess with respect to the side edges of the laminations. It will be evident, therefore, that the core flux will flow lengthwise, or in the most favorable direction throughout the full length of each lamination, with a fairly uniform distribution of the core flux throughout the cross section of the core.

As in the preceding modification, the adjacent layers of laminations are oppositely arranged as indicated by the dotted lines of Fig. 5 in order that the end portions of the laminations of adjacent layers will overlap each other. When the core clamps are applied in a manner as described above, the frictional resistance between the overlapping portions of the laminations of consecutive layers of the core will substantially preclude separation of the leg and yoke portions of the core through subsequent use of the device in which the core is incorporated.

In Fig. 6 is illustrated the manner in which the laminations for the core of Fig. 5 are produced from a long strip **35** of magnetic material which is similar to the strip **15** described above. Thus in cutting the strip generally diagonally crosswise as described above to produce a plurality of lengths, adjacent cuts are provided with portions extending in a generally diagonal direction substantially 90 degrees with respect to each other. The assembled core described above with offset diagonally extending butt joints at the corners which may be assembled from the laminations produced by the method claim herein is described and claimed in my above-mentioned copending application. As in the previous modification, in order that the laminations will fit properly together with a tight joint between the diagonal ends, the triangular projection from the diagonal should be symmetrical on the opposite sides of a perpendicular erected from the center of the diagonal.

While the invention has been described with particular reference to magnetic cores for transformers and reactors, it is obvious that the invention is applicable to magnetic cores generally, including those for motors, generators and other rotating apparatus as well as to other forms of stationary induction apparatus.

Having described the principle of my invention in what I consider to represent certain preferred embodiments thereof, I desire to have it understood that the invention is not to be limited to the specific forms described but that I intend in the appended claims to cover all such modifications as fall within the true spirit and scope of the invention.

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

1. The method of making a low loss rectangular magnetic core from rolled strip material having the most favorable magnetic direction longitudinally of the strip which comprises forming laminations by recurrently cutting across said strip along a broken line forming projections and corresponding interfitting indentations, the opposite ends of which are along a straight line at a 45-degree angle with one edge of said strip, the intermediate portion of which broken line is symmetrical on opposite sides of a perpendicular erected from the center of said straight line, then cutting across said strip along a similar broken line forming projections and corresponding interfitting indentations spaced from said first broken

line and displaced 90 degrees therefrom, and assembling the laminations with projections of laminations interfitting indentations of the adjacent laminations to form a layer for the magnetic core.

2. The method of making a low loss laminated rectangular magnetic core from rolled strip magnetic material having the most favorable magnetic direction extending longitudinally of the strip, said method comprising cutting across said strip generally at a 45-degree angle in opposite directions with respect to the magnetic direction of the strip at spaced intervals along a broken line forming projections and corresponding indentations symmetrical on opposite sides of a perpendicular erected from the center of a 45-degree line, and assembling said laminations with adjacent ends at right angles with respect to each other and with the adjacent end edges of said laminations abutting each other in a parallel relation.

3. The method of making a laminated magnetic core of high efficiency and economy for an electromagnetic induction apparatus from rolled strip material having substantially more favorable magnetic properties in the direction of rolling, said method including the steps of cutting the strip generally diagonally crosswise into a plurality of lengths with an indentation and a corresponding projection fitting and filling the indentation so as to produce a cut with substantially no scrap, providing the adjacent cuts with portions extending in a generally diagonal direction substantially 90 degrees with respect to each other, and assembling the cut lengths with a projection of a length fitting the indentation of an adjacent length to form a layer of laminations for the magnetic core.

JOHN C. GRANFIELD.