United States Patent

[11] 3,614,696

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[54] **LAMINATION CONSTRUCTION FOR TRANSFORMER CORE AND CORE INCLUDING SAME**
10 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** **336/215,** 336/217, 336/218
[51] **Int. Cl.** **H01f 27/24**
[50] **Field of Search** 336/214, 215, 216, 217, 218, 234, 212

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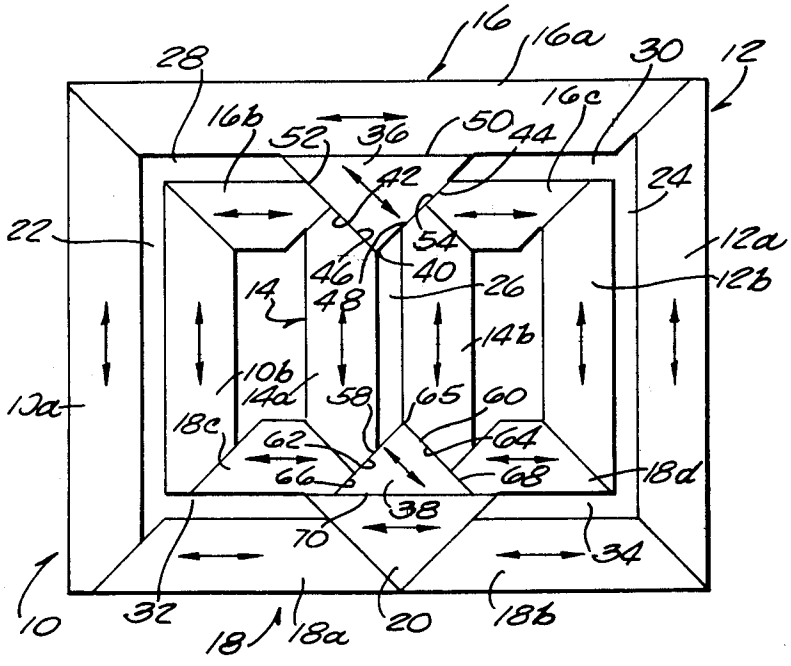
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ABSTRACT: A triangular-shaped segment is arranged at each joint between the inner leg and the yokes of a split magnetic transformer core. The triangular segments have a corner directed inwardly toward the inner leg and present two angularly related edges, i.e., on both sides of the corner, to the inner leg. These angularly related triangular segment edges abut complementary angled edges in the center leg. The grain orientation of the triangular segments is disposed at an angle of 45° to the grain orientation of both the inner leg and the yokes and perpendicular to the butt connection between the triangular segment and the inner leg. These triangular segments are offset relative to each other and with respect to the inner leg. One of the triangular segments engages an additional triangular-shaped segment provided in one of the yokes and the dimension between the inwardly facing corner and the opposite triangle segment edge abutting a yoke segment is different for both of the triangular segments.



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Fig. 1

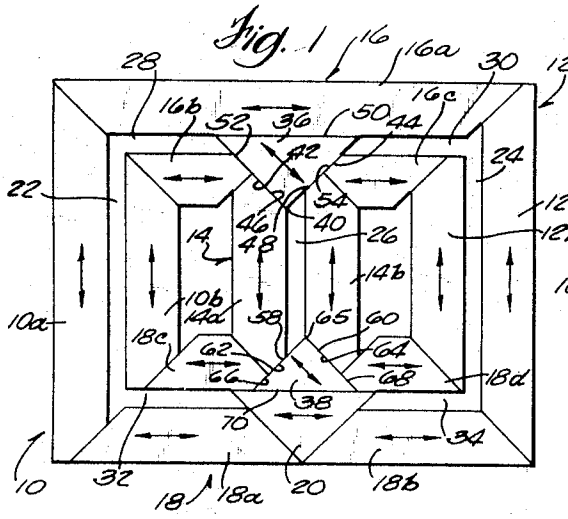


Fig. 2

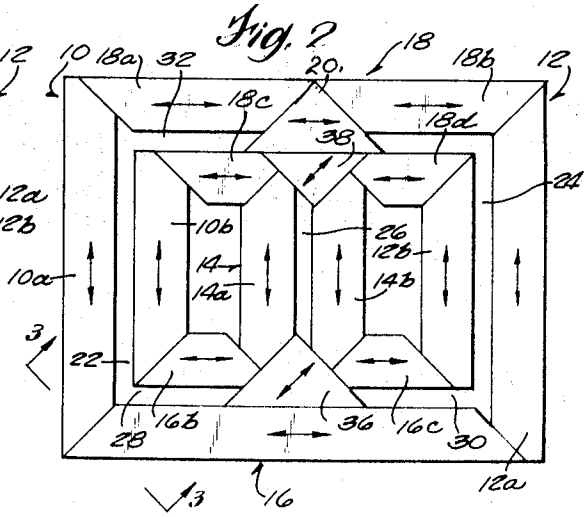
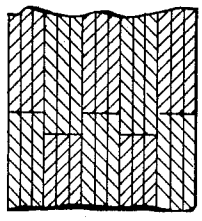


Fig. 3



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LAMINATION CONSTRUCTION FOR TRANSFORMER CORE AND CORE INCLUDING SAME

BACKGROUND OF THE INVENTION

This invention relates to transformer cores and, more particularly, to those of the split core construction.

It is commonly known that transformer characteristics such as noise, core loss, exciting current, etc. are affected by the grain orientation of the core material with respect to flux flow. In the past, various attempts have been made to achieve most effective relationship between grain orientation and flux flow, for example by piecing the transformer core together with individual lamination segments. Examples of some prior art attempts in this area can be found in U.S. Pats. Nos.

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SUMMARY OF INVENTION

This invention is concerned with this problem of improving these characteristics and contemplates doing so by achieving most effective grain orientation with respect to flux flow. Accordingly, among the general objects of this invention are to achieve a core having superior operating characteristics and to do so with a relatively simple and facilely fabricated core structure.

For the achievement of these and other objects, this invention contemplates a transformer core built up using a lamination construction having inner and outer legs and yokes connecting those legs. A triangular shaped lamination segment is positioned at the joints between the inner leg and the yokes. A corner of each of the triangular segments is directed inwardly toward the inner leg with the angularly related edges on both sides of that corner abutting complementary angled edges on the inner leg.

It is desirable that the grain orientation of the triangular lamination segment is arranged at an angle to the grain orientation of both the yoke and inner legs. Preferably, the grain orientation of the triangular segment is generally perpendicular to one of the butt joints between the triangular segment and the inner leg. This generally angular orientation of the triangular segment provides most effective grain orientation with respect to flux flow at the point of flux transfer between the inner leg and the yokes. Transformer characteristics such as those mentioned above, are thereby optimized by maintaining the angle of flux flow to grain orientation at, or closely approaching, 0° through a substantial portion of the core.

In accordance with further aspects of this invention, the triangular segments are of different size and are offset relative to each other and with respect to the inner legs so that when adjacent core laminations, identically constructed, are reversed and stacked in face-to-face relationship, an overlap is provided at each butt engagement in the joint between the inner leg and the yokes. In this regard, it is also desirable that the connection of one of the triangular segments in the yoke be accomplished by an additional triangular segment completing one of the yokes.

DESCRIPTION OF DRAWINGS

FIG. 1 is a plane view of a lamination constructed in accordance with this invention;

FIG. 2 is a plane view of an identically constructed lamination but reversed as it might be in a stacked core; and

FIG. 3 is a partial section through a part of a stacked core illustrating the laminations as they may be stacked in the core.

DESCRIPTION OF PREFERRED EMBODIMENT

FIGS. 1 and 2 illustrate a lamination adapted for use in a three-legged, three-phase split magnetic core. The invention also is adapted for use in other types of magnetic cores.

The layers of laminations which are used to make up the core are identically constructed and, accordingly, the details of only one layer of lamination will be described. It will be appreciated that this description is applicable to all of the layers of core laminations. Moreover, it will also be appreciated that the description of the layers of laminations in FIG. 1 is applicable to the layer of laminations of FIG. 2 which is merely a reversal of the layer of laminations of FIG. 1. That is, the layer of laminations of FIG. 1 is turned upside-down (as viewed in the drawing) to provide the layer of laminations of FIG. 2. To better illustrate this identity and reversal, the same numbers will be used to identify corresponding major segments in the layer of laminations of both FIGS. 1 and 2.

The layer of laminations includes parallel outer legs **10** and **12** and an inner leg **14**. These inner and outer legs are connected, in FIG. 1, by an upper yoke **16** and a lower yoke **18**. The layer of laminations is what is commonly termed a split construction. More specifically, outer legs **10** and **12** consist of spaced lamination segments **10***a*, **10***b* and **12***a*, **12***b* respectively. Inner leg **14** consists of lamination segments **14***a* and **14***b*. Upper yoke **16** includes yoke segments **16***a*, **16***b* and **16***c*. Lower yoke **18** includes yoke segments **18***a*, **18***b*, **18***c*, **18***d* and triangular segment **20** which will be discussed more completely hereinafter. These lamination segments are relatively spaced apart providing airgaps therebetween. Gaps **22** and **24** are provided in legs **10** and **12** and airgap **26** is provided in inner leg **14**. Similarly, gaps **28** and **30** are provided in upper yoke **16** and gaps **32** and **34** are provided in lower yoke **18**.

In operation of a core constructed with three-legged lamination configuration as just described, the flux distribution in the core will vary whereby flux may be shared, at given times with a cycle, through the yokes by all legs, the inner leg with one and then the other outer leg, or both outer legs without the inner leg. A low reluctance path is desired for the flux. The core laminations are made from grain orientated steel and, since a grain orientation parallel to flux flow provides far superior results in this respect as compared to the grain orientation at any other angle to flux flow, the grain orientation of the segments making up the lamination legs and yokes is preferably such as to be in the direction illustrated by the double headed arrows in FIGS. 1 and 2. These arrows also depict generally the direction of flux flow through these members. It will also be noted that the joints between the outer leg lamination segments and the yoke lamination segments are mitered which provides an effective turning path for the flux and maintains the flux as nearly as possible in a parallel direction to the grain orientation even at the corner joints. In other words, at the mitered joints the flux will tend to turn into the adjacent lamination segments at an angle to the joint thus positioning the flux most effectively for orientation with respect to the grain direction of that adjacent lamination segment. The provision of the low reluctance path also bears on other characteristics of the transformer such as noise, core losses and exciting current.

This flux distribution results in the flux, at various times, flowing into and out of the inner leg either in one direction to or from one outer leg or to or from the other outer leg in an opposite direction or, simultaneously, to or from both outer legs. It can thus be seen that the direction of flux flow between the inner leg and the yokes will reverse itself during a given cycle. Thus, the grain orientation at the joint between the inner leg and yokes is particularly critical.

This invention is concerned with this problem of flux transfer between the inner leg and the yokes and proposes as a solution to that problem the use of triangular shaped segments **20** **36** and **38**.

More specifically, triangular segment **36** is positioned with corner **40** thereof directed inwardly toward leg **14**. The angularly related edges **42** and **44** of the segment abut complementary angled edges **46** and **48** of inner leg segments **14***a* and **14***b*. Side **50** of segment **36** opposite corner **40** abuts outer yoke segment **16***a*. It will also be noted that angular edges **42** and **44** also abut complementary angled edges **52** and **54** of

inner yoke segments 16*b* and 16*c*. Similarly, triangular segment 38 includes corner 65 directed inwardly toward leg 14 and having angularly related edges 58 and 60 on opposite sides of that corner which abut complementary angled surfaces 62,64 of leg segments 14*a* and 14*b*, and 66,68 of yoke segments 18*c* and 18*d*. Side 70 opposite corner 65 abuts triangular yoke segment 20 for a reason which will be described hereinafter. With this construction a generally mitered connection is provided between the triangular segments and the inner leg segments and through the area of the transition from the inner leg to the yokes. This type of joint, i.e., utilizing the triangular segment, most effectively directs the flux flow in the transition between the inner leg and the yokes.

Preferably the grain orientation of the triangular segments is at an angle to the grain orientation of both the inner leg and the yokes. This even more effectively directs the flux between the leg and the yokes. Furthermore, it is preferred that the grain orientation of the triangular segments be at an angle to at least one of the butt joints with the inner leg for optimum flux transference. As illustrated, triangular segments 36 and 38 are right triangles, i.e., corners 40 and 65 define a right angle and the grain orientation of the triangular segment is at 45° to the vertical, in or 45° to the grain orientation of the inner leg, and at right angles to the butt joint between surfaces 44,48 and 58,62.

In stacking the laminations in face-to-face relationship to build up the transformer core, the laminations are periodically reversed (turned upside-down as illustrated in FIGS. 1 and 2). The laminations are reversed in this manner so that an overlap will occur at each of the butt joints in the lamination. This provides the overlap for the flux transfer at each butt joint. With reference to FIGS. 1 and 2, it can be seen that if the layer of lamination oriented as in FIG. 1 is placed over the layer of lamination as oriented in FIG. 2, an overlap will occur at each one of the butt joints.

In this regard, it should be noted that triangular segments 36 and 38 are of different sizes, i.e., the distances from the respective corners 40 and 65 to the opposite side 50 and 70 are different. In other words, triangular segment 36 extends beyond inner yoke segments 16*b* and 16*c* to directly engage outer yoke segment 16*a*. In contrast, triangular segment 38 terminates in general alignment with inner yoke segments 18*c* and 18*d* and triangular segment 20 extends beyond outer yoke segments 18*a* and 18*b* for direct engagement with edge 70 of triangular segment 38. In this manner, when the laminations are reversed an overlap of the butt joints in the area of triangular lamination segments 36 and 38 is provided.

At this point it should also be noted that the grain orientation of triangular segments 36 and 38 in a given lamination is in the same direction. With this arrangement, when the laminations are reversed, the grain orientation of the triangular inserts of adjacent, reversed laminations are at an angle to each other, in the illustrated embodiment at right angles to each other. The significance of this reversal of the grain orientation is that, with reference to FIGS. 1 and 2, the triangular segments in a given lamination are arranged for optimum flux transference from the inner leg toward one of the outer legs whereas the triangular inserts of an adjacent, reversed lamination are arranged for optimum flux transference from the inner leg toward the other outer leg. Accordingly, an optimum compromise is effected with this construction. It should also be noted at this point that the improvement in flux transfer where the grain orientation is generally parallel to flux flow is substantially greater than that which is encountered where the flux is at right angles to grain orientation so that the advantages gained from directing flux through the triangular segments parallel to grain orientation far exceed the disadvantages of directing flux through the triangular segments at right angles to its grain orientation. For example, and with reference to FIG. 1, the improvement in transfer of flux from segment 14*b* through triangular segment 36 toward outer leg 10 is substantially greater than the lessening of flux transfer from segment 14*b* through triangular segment 36 toward leg 12 and the advantage greatly outweighs the disadvantage in the arrangement and an overall improved operation is achieved. This is further optimized by the reversal in grain orientation of the triangular inserts between adjacent, reversed laminations as described above, in that through the stack a number of the segments will always be properly oriented for most effective flux flow regardless of the direction of that flow.

It should also be noted at this point that in discussing stacking of laminations such as those illustrated in FIGS. 1 and 2 to build up the core, conventionally a number of similarly oriented laminations are stacked before the reversal is made. As illustrated in FIG. 3, the laminations are preferably stacked in series of three with adjacent stacks of three similarly oriented laminations being reversed.

With the arrangement just described, a relatively simple lamination construction is achieved and one which exhibits superior characteristics. More specifically minimum reluctance to flux flow is maintained throughout the layer of laminations and this results in a core having a relatively low noise level, relatively low-core losses, and requiring relatively low exciting current. It has been observed that the noise level in a core built in this manner approaches that of a conventional, nonsplit core and is greatly reduced as opposed to other types of split core constructions. Moreover, the core losses and exciting currents of cores constructed with the herein described laminations and conventional nonsplit cores are approximately the same whereas these characteristics are substantially reduced as compared to other types of split core constructions.

We claim:

1. A lamination construction for a split magnetic transformer core comprising, in combination,

a pair of outer legs,

a split inner leg made up of first and second spaced lamination segments,

said inner and outer legs being generally parallel and also having a generally parallel grain orientation,

yoke segments connecting corresponding ends of said inner and outer legs and having a grain orientation generally perpendicular to the grain orientation of said legs,

first and second triangular shaped lamination segments disposed one at each of the joints between the yoke segments and each of the opposite inner leg ends, each of said triangular segments arranged with a corner thereof directed inwardly and with the angularly related edges on both sides of said corner abutting complementary angled edges on the lamination segments forming the inner leg,

said first and second triangular segments having a grain orientation at an angle to the grain orientation of both said inner leg and said yoke segments,

one of the yokes formed by said yoke segments including a third triangular segment having an edge abutting an edge of said first triangular segment and providing the connection of said first triangular segment to its respective yoke,

and the grain orientation of said third triangular segment being parallel to that of said yoke of which said third triangular segment is a part.

2. The core lamination of claim 1 wherein the grain orientation of said first and second triangular segments is generally perpendicular to one of the butt joints between said first and second triangular segments and said inner leg.

3. The core lamination of claim 1 wherein the angle of the grain orientation of the first and second triangular segments to that of said yoke segments and said inner leg is approximately within the range of 35°–55°.

4. The core lamination of claim 3 wherein said angle of triangular segment grain orientation to the grain orientation of said yoke segments and inner leg is approximately 45°.

5. The core lamination of claim 1 wherein

said first and second triangular segments have relatively different dimensions from the inwardly facing corner thereof to the butt connection with said yoke segment and said third triangular segment,

and said first and second triangular segments are offset relative to each other and with respect to said inner leg,

whereby when two of said laminations identically constructed are reversed an overlap is provided at each butt engagement in the joints between the inner leg and yoke segments.

6. A transformer core comprised of laminations in accordance with claim **1** wherein said laminations are stacked and periodically reversed with the grain orientation of said triangular segments of adjacent reversed laminations generally overlapping each other and being oppositely angled relative to each other.

7. A split magnetic transformer core comprising stacked laminations, each of said laminations comprising

first and second outer generally parallel, spaced legs,

a split inner leg made of first and second spaced lamination segments arranged generally parallel to said outer legs,

said inner and outer legs being generally parallel and also having generally parallel grain orientations,

first and second yokes each including inner and outer parallel, spaced yoke segments and connecting corresponding ends of said inner and outer legs,

said yoke segments have a grain orientation generally perpendicular to the grain orientation of said legs,

first and second triangular shaped lamination segments disposed one in each of the joints between the yokes and each of the opposite inner leg ends, each of said first and second triangular segments arranged with a corner thereof directed inwardly toward the inner leg and the angularly related edges on both sides of said corner abutting complementary angled edges in said inner yoke segments and in the lamination segments forming the inner leg,

said first and second triangular segments have a grain orientation at an angle to the grain orientation of both said inner leg and said yoke segments,

the grain orientations of said first and second triangular segments being generally in the same direction so that when stacked the grain orientations of relatively reversed first and second triangular segments are oppositely angled,

said first triangular segment projecting beyond said inner yoke segment and abutting the outer yoke segment of one said yokes and the other yoke including a third triangular segment in the outer segment thereof and projecting beyond that outer segment and abutting said second triangular segment,

the grain orientation of said third triangular segment being parallel to that of said yoke of which said third triangular segment is a part,

and said first and second triangular segments being offset relative to each other and with respect to said inner leg,

whereby when said laminations are stacked and periodically reversed an overlap is provided at each butt connection in the inner leg joint with said yokes.

8. The core of claim **7** wherein the grain orientation of each of said first and second triangular segments is generally perpendicular to one of the butt joints between said first and second triangular segments and said inner leg.

9. A lamination construction for a magnetic transformer core comprising, in combination,

a pair of outer legs,

an inner leg,

yoke segments connecting corresponding ends of said inner and outer legs,

first and second triangular shaped lamination segments disposed one at each of the joints between the yoke segments and each of the opposite inner leg ends, each of said triangular segments arranged with a corner thereof directed inwardly toward the inner leg and the angularly related edges on both sides of said corner abutting complementary angled edges on the lamination segments forming the inner leg,

one of the yokes formed by said yoke segments including a third triangular segment and providing the connection of said first triangular segment to its respective yoke,

and said first and second triangular segments having a grain orientation at an angle to one of the butt joints between said first and second triangular segments and said inner leg and the grain orientation of said third triangular segment being parallel to that of said yoke of which said third triangular segment is a part.

10. The lamination of claim **9** wherein said first and second triangular segments have a grain orientation generally perpendicular to one of the butt joints between said first and second triangular segments and said inner leg.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,614,696 Dated October 19, 1971

Inventor(s) James D. Douglass and Albert T. Chase

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Claim 9, column 6, line 31, after "segment" and before "and" insert --having an edge abutting an edge of said first triangular segment--.

Signed and sealed this 18th day of April 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents