March 29, 1949. M. P. WINTHER 2,465,983

TOOTHED POLE RING FOR DYNAMOELECTRIC MACHINES

Filed April 24, 1947 2 Sheets-Sheet 1

FIG. 1.

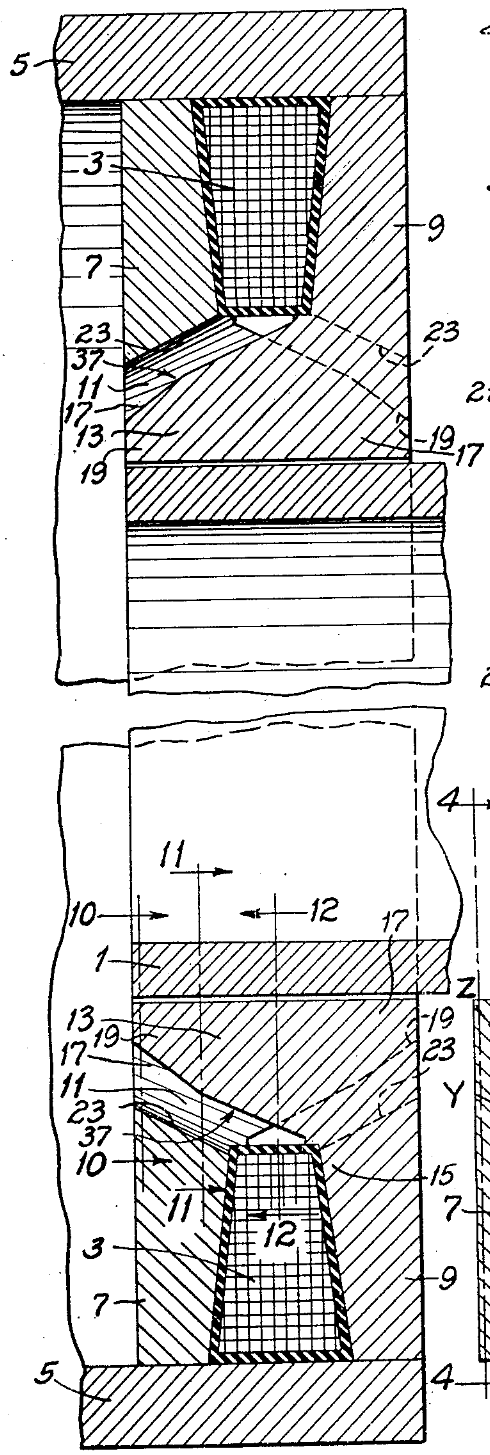
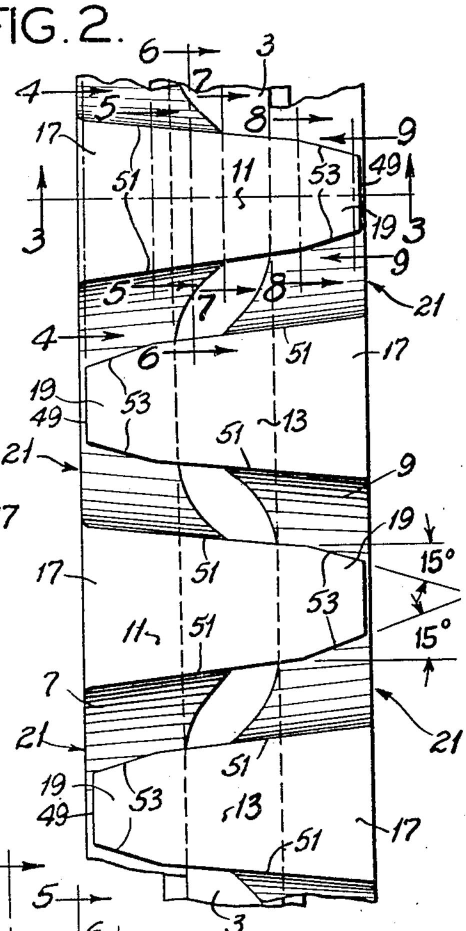


FIG. 2.



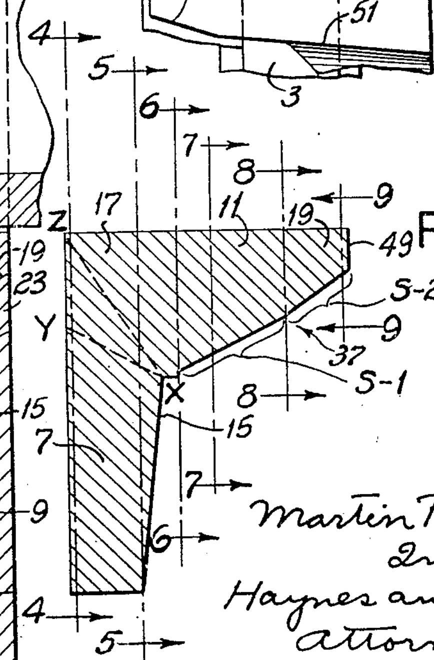


FIG. 3.

Martin P. Winther,
Inventor.
Haynes and Koenig,
Attorneys.

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Filed April 24, 1947 2 Sheets-Sheet 2

FIG. 4.

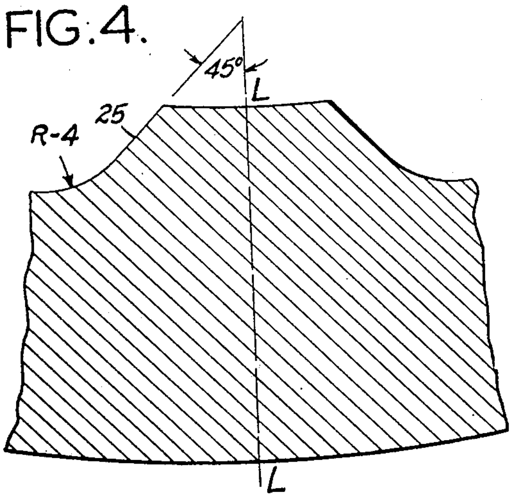


FIG. 5.

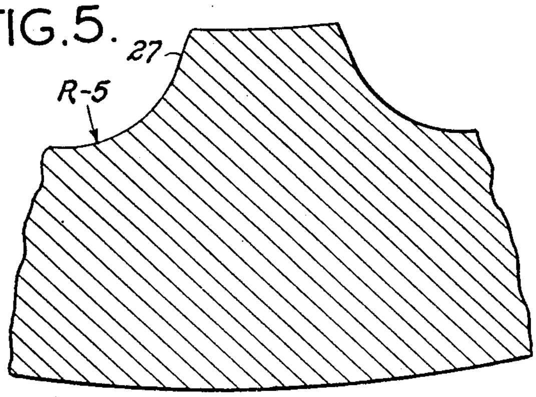


FIG. 6.

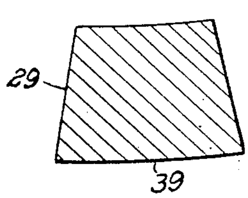


FIG. 7.

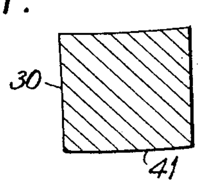


FIG. 8.

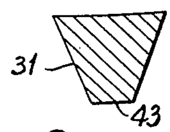


FIG. 9.

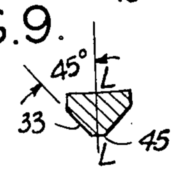


FIG. 10.

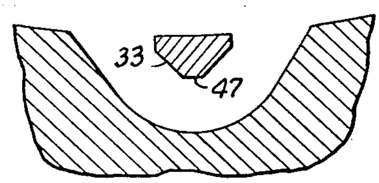


FIG. 11.

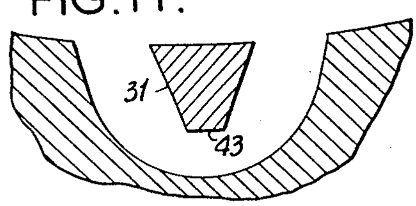


FIG. 12.

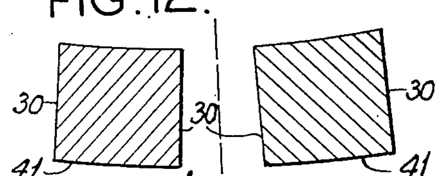
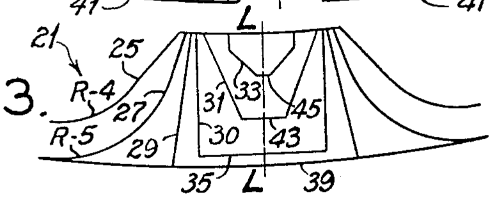


FIG. 13.



Martin P. Winther,
Inventor.
Haynes and Koenig,
Attorneys.

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UNITED STATES PATENT OFFICE

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TOOTHED POLE RING FOR DYNAMO-ELECTRIC MACHINES

Martin P. Winther, Waukegan, Ill., assignor to Martin P. Winther, as trustee

Application April 24, 1947, Serial No. 743,668

8 Claims. (Cl. 171—252)

1

This invention relates to toothed pole rings for dynamoelectric machines, and with regard to certain more specific features, to imbricated rings of the class described for eddy-current machines.

Among the several objects of the invention may be noted the provision of improvements upon imbricated toothed ring structures such as shown, for example, in United States Patents Nos. 2,367,163 and 2,367,636; the provision of means for successfully carrying out in the imbricated toothed structures such as shown in said patents the improvements specified in United States Reissue Patent 20,225 (original 1,977,600) and in United States Patent 2,197,990; the provision of a structure of the class described which without increase in size of the imbricated-tooth apparatus to which it applies will greatly increase unit torque; and the provision of apparatus of the class described which substantially increases the weight efficiency of machines to which it is applied. Other objects will be in part apparent and in part pointed out hereinafter.

The invention accordingly comprises the elements and combinations of elements, features of construction, and arrangements of parts which will be exemplified in the structures hereinafter described, and the scope of the application of which will be indicated in the following claims.

In the accompanyng drawings, in which one of various possible embodiments of the invention is illustrated,

Fig. 1 is a longitudinal section through pertinent parts of apparatus embodying the invention;

Fig. 2 is an inside developed plan view of the imbricated teeth and pole rings shown in Fig. 1, the eddy-current inductor of Fig. 1 being removed;

Fig. 3 is a view similar to Fig. 1, but showing a radial section through one tooth on one side of one ring;

Figs. 4–9 are fragmentary detail sections taken on lines 4—4, 5—5, 6—6, 7—7, 8—8 and 9—9, respectively, of Figs. 2 and 3;

Figs. 10–12 are fragmentary sections taken on lines 10—10, 11—11, and 12—12, respectively of Fig. 1; and,

Fig. 13 is an end view of a tooth viewed from the right of Fig. 3 and showing contour lines corresponding to the cross section shown in Figs. 4–9, respectively.

Similar reference characters indicate corresponding parts throughout the several views of the drawings.

The present invention is applicable to toothed

2

structures for eddy-current machines employing relatively movable magnetic pole and inductor members, such as in eddy-current slip couplings, brakes, dynamometers and the like. As shown in said Reissue Patent 20,225, such machines may have salient poles with individually wound field coils; or as shown in Patent 2,197,990, they may have belts of toothed poles on opposite sides of an annular field coil; and as shown in said Patents 2,367,163 and 2,367,636, they may have overlapping or imbricated poles.

In Patent 2,197,990 and Reissue 20,225, it was taught that for best operating efficiency the flux emanating from the toothed ends, after leakage flux has been taken account of, should be evenly distributed and of high or substantially saturating magnitudes from the pole end areas. In Patents 2,367,163 and 2,367,636 it was taught how tooth overlap would improve certain torque characteristics. However, it has heretofore been the normal characteristic of claw type overlapped or imbricated teeth that they will not operate at high even flux densities over the toothed areas facing the inductor drum. The present invention shows how imbricated belts of polar teeth may be geometrically formed to produce from substantially the entire tooth area facing the inductor an even flux distribution of high density, preferably approaching saturation.

Referring now more particularly to Fig. 1 there is shown at numeral 1 a homogeneous inductor drum of an eddy-current machine. This may be its driving or driven member if a slip coupling, and either the rotating or the stator member if a brake or dynamometer. At numeral 3 is shown an annular field coil in a cylindric magnetic member 5. Fastened to the member 5 on opposite sides of the coil 3 are magnetic pole rings 7 and 9, which are respectively formed with the imbricated magnetic pole teeth 11 and 13. These with the rings form the subject of the invention. The rings 7 and 9 are attached to the drum 5 as by welding or otherwise. The assembly of parts 3, 5, 7, 9, 11, 13 all rotate as a unit and may form the driving or driven member if the device is a slip coupling; and either the rotating or stationary member if the device is a brake or dynamometer. Details of the rotary or other mountings for either of the relatively rotary assemblies thus far described are not included, since such form the known parts of apparatus to which the invention applies, as shown for example by said patents.

The rings 7 and 9 carry their respective pole teeth 11 and 13 in peripherally spaced relationship. The teeth or poles extend oppositely, overlapping when peripherally considered around the coil 3 (Fig. 2). Throughout their faces these poles are spaced a predetermined constant distance from the inductor 1, as is clear from Fig. 1. Thus the toric flux field which is generated by the coil 3 completes a circuit through members 5, 7, 11, thence into the inductor 1, then escaping from the inductor into the pole teeth 13 and completing the circuit through the ring 9 and back to member 5. Or, the sequence of this circuit may be reversed. This means that one set of pole teeth such as, for example, 11 assumes one polarity (north, for example) and the other set of teeth 13 assumes the opposite polarity (south, for example). The pole teeth act as flux concentrators or field distorters, so that as the flux field sweeps the inductor 1 due to relative motion, eddy-currents are set up in the inductor whereby a magnetic reactive driving torque results. This is used either for driving drum 1 from the rotating pole teeth or vice versa.

Before the flux reaches a point where it leaves those areas of the teeth 11 and 13 exposed to the inductor 1 (see the top tooth areas in Fig. 2), leakage tends to occur from the flux circuit. This leakage flux never appears at said areas. It is the purpose of the special forms of the teeth herein to be described to assure that the next flux (after leakage has been subtracted) which emanates from the faces of the teeth 11 and 13 (shown in Fig. 2) shall be high and even throughout said areas as the flux leaves these areas to enter the drum 1.

To attain the above ends, the rings 7 and 9 may be tapered to enlarge radially towards the pole teeth, as shown at 15, although this feature is optional. The general form of each pole tooth 11 and 13 is that of an anvil having a heel or root portion 17 and a toe or end portion 19. Hereinafter, since both toothed rings 7 and 9 are identical, only one ring will be described unless otherwise noted. Ring 7 with teeth 11 being chosen for the purpose. Also, since all teeth are identical, only one will be described in detail.

The heel or root 17 is made integrally with the ring 7, notches 21 being formed in the ring between teeth where they join the ring. Each notch has a bottom or valley of a hollow substantially conical form, the bottom of the valley of which is indicated by the straight line 23 in Fig. 1, and the radii of curvatures of which increase in progression from the outside of the ring to the inside, as shown at R—4 and R—5 in Figs. 4 and 5, respectively. Thus the valleys of the notches increase in size starting from the outside of the pole ring and in the direction of the opposite pole. The sections under consideration are normal to the axis of the ring concerned, being right sections. This makes a conical saddle shape for the bottom of each notch 21 in the thickest part of the ring 7. This saddle shape widens towards the coil 3. The side portions of each notch which form the adjacent sides of the adjacent teeth are formed by straight right lines in successive right planes advancing from the heel 17 toward the toe 19. The lines continue to the ends of the teeth after leaving the notches. These successive lines are shown at numerals 25, 27, 29, 30, 31, and 33 in Figs. 9–4, respectively; also in the other figures wherein they occur. For example, in Fig. 13 these lines are indicated as contour lines looking from the end of a tooth. All such lines, out to line 29 which is in the inside plane of the ring, are tangent to said circles of increasing radii of the conical bottom of the notch 21 (see Figs. 4, 5, 10 and 13). The line 25 on the outside of the ring is at approximately 45° angle (assumed positive) with a radial plane L—L through the axis of the ring (see Fig. 4). The line 33 (Fig. 9) is at 45° negative angle with respect to the same plane L—L. Lines such as 27, 29, 30 and 31 (Figs. 5–8, inclusive) located between the extreme lines 25 and 33 have progressively decreasing positive and finally increasing negative angles from line 25 to line 33. Thus the sides of the anvil-shaped teeth may be said to have right lines which form a warped or twisted surface forming the sides of said teeth. By right lines is meant lines in planes at right angles to the axis of the ring. The twist is from a positive direction in the heel or root to a negative direction in the toe or end. The resulting twisted surface in the region of the heel is always tangent to right circles of the conical form of the base of the adjacent notch. It will be clear from the above that one of these lines 30 will have almost zero angle with respect to the plane L—L (see Figs 7, 12 and 13), which forms practically a square cross section for the tooth just outside of the ring 7. The bottoms of the teeth sections are formed by a straight line 35 at this point. The tops are almost straight lines ignoring the slight curvature used for the top surface of the tooth where it faces the inductor 1.

In addition to each tooth having sides warped or twisted as stated, the bottom (indicated generally at 37) is tapered from the root to the end. The taper on the bottom is in two sections S—1 and S—2 (Fig. 3). Successive lines forming the bottoms of section S—1 are shown in Figs. 6, 7 and 8 as line 39, 41 and 43, respectively. Fig. 12 also shows line 41. These lines are straight or nearly so and practically form a sloping plane in section S—1. The tapered section S—2 has a sharper slope than the section S—1 forming the toe of the anvil or end of the tooth, and the lines 45 and 47 of Figs. 9 and 10 are in this section. Also, the edges 51 of the tooth above the section S—1 are slightly tapered, and this taper is increased to about 15° for the edges 53 above the region S—2 (see Fig. 2). The ends 49 of the teeth are flat.

The purpose of forming the notches 21 and the teeth 11 as above described is to produce flux feed cross sections X—Y and X—Z (Fig. 3) in the heel 17 of about constant area with right sections through the tooth extensions (such as sections 6—6, 7—7, 8—8 and 9—9 of Fig. 3) of progressively reduced flux transmitting areas. Thus leakage of flux is minimized up to the point where it enters the tooth proper. Thereafter as successive amounts of flux are lost by leakage and from the tooth face into the inductor 1, the magnetic sections for flux supplying the remainder of the tooth are cut down so as to maintain constant flux densities from unit areas of the tooth face up to its end. The densities can be held at near saturation for the particular material forming the rings and teeth by sufficiently exciting the coil 3.

A point to be noted is that the edges of adjacent teeth when viewed from their inner faces are more or less parallel for a long distance and, what is equally important, this substantial parallelism is maintained on the tooth sides because the twisted side of one tooth is inversed to the twisted side of the adjacent and oppositely extending tooth. It should also be noted from Fig. 1 that there is a substantial parallelism between the bottom of each tooth or pole and the lower line 23 of each conical notch, the bottoms of the poles sloping in substantially the directions of the conical valleys of the notches. Thus the notch and heel portion of each tooth is the negative counterpart of the solid toe portion of each tooth but spaced therefrom, thereby maintaining a fairly constant leakage distance throughout all tooth and notch areas. Thus whatever cross leakage occurs between teeth is more or less uniform throughout the lengths of the teeth. This makes feasible the designing of right sections of each tooth from heel to toe, which will maintain the high flux concentration emanating from the tooth and entering the inductor at a substantial constant value throughout the tooth length. By this means it is possible to have in one field structure the advantages of an even and high or saturation flux emanating from the entire tooth face into the inductor, which was not heretofore attained in the case of overlapping or imbricated teeth. In other words, the present invention for the first time makes possible the use of the teachings of Reissue Patent 20,225 and Patent 2,197,990 in imbricated tooth structures such as shown in Patents 2,367,163 and 2,367,636.

It will be understood that while the invention is shown with the inductor 1 inside of the imbricated-toothed rings 7 and 9, the invention can be carried out with the inductor member arranged externally with the member 5 internally, the teeth 11 and 13 being outside of the coil. Or they could be on one side with the inductor axially arranged. This would be mere inversions and require no further description.

It is to be understood that while the arcs such as shown at R—4 and R—5 are circular, equivalent curves may be used within the teachings of the invention. Also, although straight lines are preferable for the twisting sequence of lines 25—33, similar lines may be used in a twisted arrangement, the lines in the heel portion of the tooth being tangent to the arcuate lines in the valley of the notch, as specified.

While the invention has been described in connection with eddy-current machines, it will be understood that it can be applied to dyamoelectric machines in general wherever the stated characteristics of high flux densities of the order of flux saturation are desired at the pole ends.

It is to be understood that while even flux saturation is desired across the tooth surfaces facing the inductor 1, the invention is intended to cover cases wherein the flux density is high if not quite at saturation, one of the features of the invention being to maintain evenness of flux density through said tooth face.

A way of considering the essence of the invention is that each tooth has a root portion at its ring, the right or transverse sections of which are the larger group of figures comprising symmetrical substantial quadrilaterals with their short sides adjacent the inductor, and the toe portions of which are the group of smaller figures comprising substantial quadrilaterals with their long sides adjacent the inductor; the notches in the rings being semiconical, the small sides of the smaller quadrilaterals being adjacent to the valley portions of the notches.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As many changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. A pole structure for a dynamoelectric machine having an inductor, an annular field coil and magnetic pole rings enveloping the coil; comprising oppositely directed imbricated poles extending from said rings across the coil and having pole faces spaced a predetermined constant distance from the inductor throughout the pole faces, each ring having notches between its poles, the valleys of which notches increase in size starting from the outside of the pole ring and in the direction of the opposite pole, each pole being formed axially at its root portion in the ring by a series of similarly shaped transverse sectional figures the shorter sides of which are adjacent the inductor, and the toe portions of which poles beyond the ring are formed by a series of similarly shaped tranverse sectional figures the longer sides of which are adjacent the inductor.

2. A pole structure for a dynamoelectric machine having an inductor, an annular field coil, and magnetic pole rings enveloping the coil; comprising oppositely directed imbricated poles extending from said rings across the coil and having pole faces adjacent the inductor, each ring having notches between poles, the valleys of which notches are substantially conical and increasing in size in the direction of the opposite pole, each pole being formed axially substantially by a series of lines progressing in a twisting sequence through the notches and to the pole ends, the bottoms of the poles sloping in substantially the directions of the conical valleys of said notches.

3. A pole structure for a dynamoelectric machine having an inductor, an annular field coil, and magnetic pole rings enveloping the coil; comprising oppositely directed imbricated poles extending from said rings across the coil and having pole faces adjacent the inductor, each ring having notches between poles, the valleys of notches being formed by right circles increasing in size in the direction of the opposite pole, each pole being formed axially substantially by a series of right lines progressing in a twisting sequence through the notches and to the pole ends, the bottoms of the poles sloping in substantially the directions of the conical valleys of said notches, the right lines in the regions of the notches being tangent respectively to right circles in the notches.

4. A pole structure for a dynamoelectric machine having an inductor, an annular field coil, and magnetic pole rings enveloping the coil; comprising oppositely directed imbricated poles extending from said rings across the coil and having pole surfaces adjacent the inductor, each ring having an increasing thickness in a direction approaching its poles and having notches between poles, the valleys of which notches are substantially conical and increasing in size in the direction of the opposite pole, each pole having sides formed axially and substantially by a series of right lines progressing in a twisting sequence from a positive 45° angle at the small end of the adjacent notches to a negative 45° angle adjacent the pole end, the bottoms of the poles sloping in substantially in the directions of the conical valleys of said notches.

5. A pole structure for dynamoelectric machines having an inductor, an annular field coil,

and magnetic pole rings enveloping the coil; comprising oppositely directed imbricated poles extending from said rings across the coil and having pole faces adjacent the inductor at a predetermined distance throughout the pole faces, each ring having notches between poles, the valleys of which notches are substantially conical and increasing in size in the direction of the opposite pole, each tooth being formed axially at its root portion in the ring by a series of radially symmetrical substantial quadrilaterals the short sides of which are adjacent the inductor and the toe portions of which are formed by a series of symmetrical substantial quadrilaterals with their long sides adjacent the inductor, the quadrilaterals in the toe portions of the pole gradually decreasing in area.

6. A pole structure for a dynamoelectric machine having an inductor, an annular field coil and magnetic pole rings enveloping the coil; comprising oppositely extended imbricated poles extending from said rings across the coil and having pole faces spaced a predetermined constant distance from the inductor throughout the pole faces, each pole having notches between its teeth, the valleys of which notches increase in size starting at the outside of the pole ring and in the direction of the opposite pole, each pole being formed at a root portion in the ring by a portion converging toward the inductor and in its extension being formed by a radial portion converging away from the inductor.

7. A pole structure for a dynamoelectric machine having an inductor, an annular field coil and magnetic pole rings enveloping the coil; comprising oppositely extended imbricated poles extending from said rings across the coil and having pole faces spaced a predetermined constant distance from the inductor throughout the pole faces, each ring having notches between its poles, the valleys of which notches increase in size in the direction of the opposite pole, each pole being formed at a root portion in the ring by a portion converging toward the inductor and in its extension being formed by a radial portion converging away from the inductor, each pole also being formed with an axial taper in a direction away from its root.

8. A pole structure for a dynamoelectric machine having an inductor, an annular field coil and magnetic pole rings enveloping the coil; comprising oppositely extended imbricated poles extending from said rings across the coil and having pole faces spaced a predetermined constant distance from the inductor throughout the pole faces, each ring having notches between its poles, each pole being formed at a root portion in the ring by a portion converging toward the inductor and away from the adjacent notch and in its extension being formed by a radial portion converging away from the inductor.

MARTIN P. WINTHER.

REFERENCES CITED

The following references are of record in the file of this patent:

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