

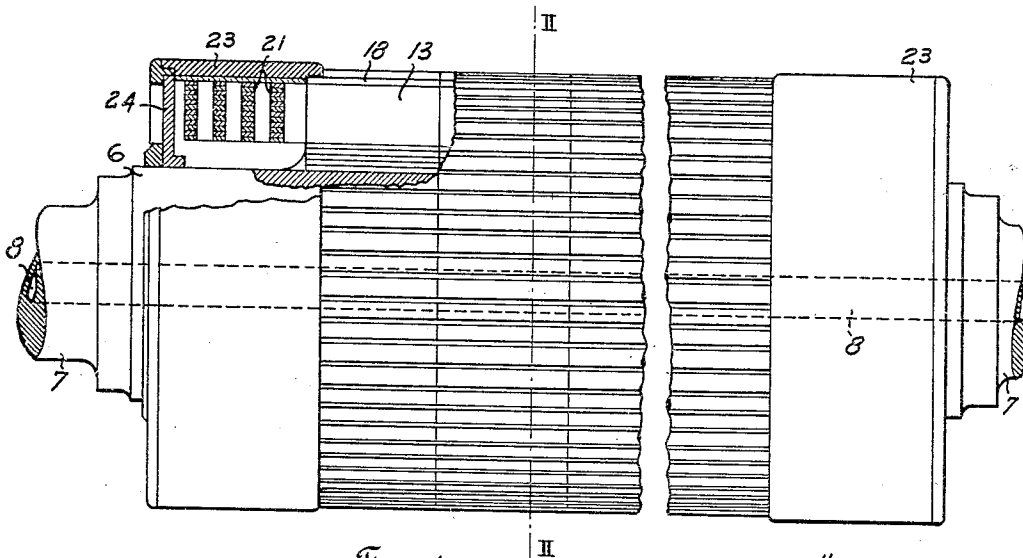
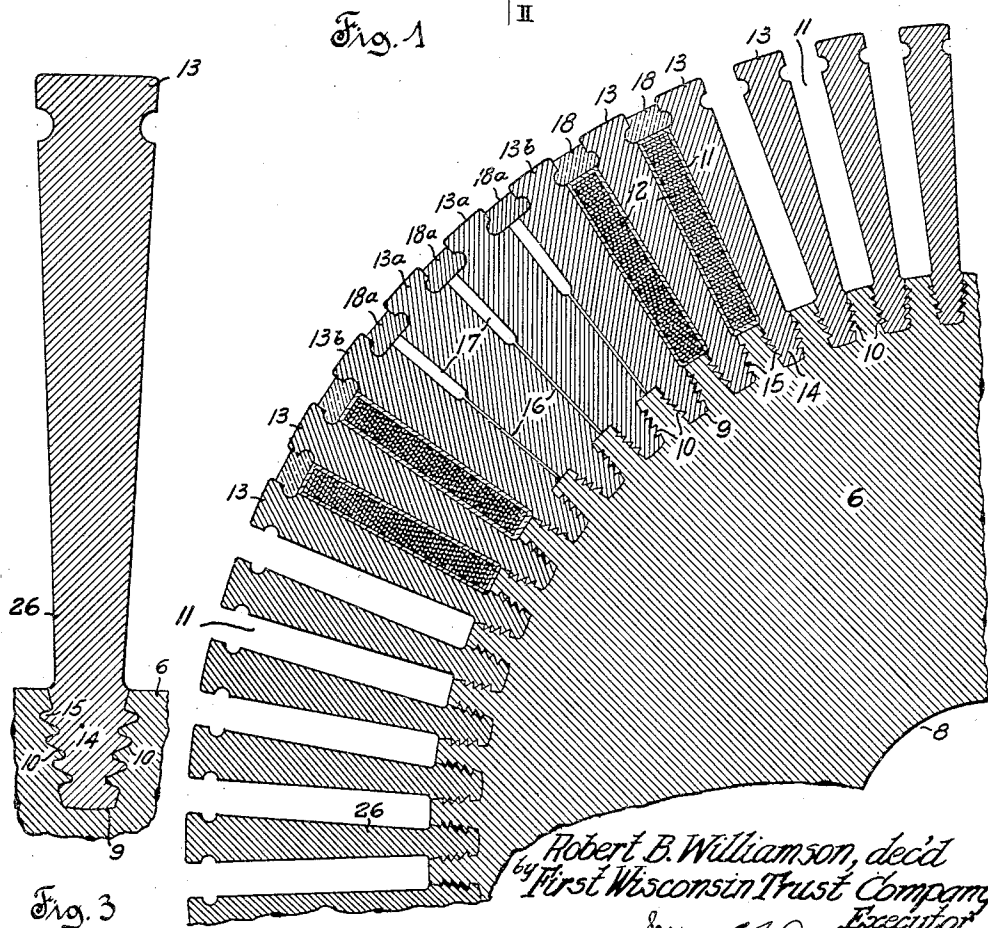
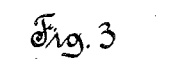
March 3, 1936.

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2,033,059

DYNAMO-ELECTRIC MACHINE ROTOR CONSTRUCTION

Filed Oct. 26, 1933



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UNITED STATES PATENT OFFICE

2,033,059

DYNAMO-ELECTRIC MACHINE ROTOR
CONSTRUCTION

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Application October 26, 1933, Serial No. 695,296

13 Claims. (Cl. 171—206)

The present invention relates in general to the design and construction of dynamo-electric machines, and it has more particular relation to rotor elements constituting field cores of turbo-generators of relatively great size and capable of operation at high speeds such as are an incident to driving the rotor by a steam turbine through a direct connection therewith.

In the effort to increase efficiency and economy of operation of and minimize space required by electrical power units, particularly turbo-generators intended to be direct driven by steam turbines, the sizes of the individual turbo-generators for operation at synchronous speeds of 1800 R. P. M. and 3600 R. P. M. have gradually advanced so that now it is common to build such generators of sizes considerably upward of 50,000 kw. capacity, and individual machines of as high as 150,000 kw., and even higher, capacity are being designed and built. Due to the great stresses imposed by centrifugal force on the rotor core and the windings thereon at the high operating speeds, the diameter of the rotor must be held to a minimum value, and the core with its shaft is of greatest strength reasonably possible with due consideration to required magnetic characteristics and expense of production of the core.

As a means of obtaining the desired objectives in the design of rotors for turbo-generators of large size which are satisfactory from the standpoint of mechanical and electrical operation and also from the standpoint of commercial economy, it has been customary practice to produce rotor cores forged from steel ingots, the core being usually in the form of a single forging including the rotor core proper and end stub shafts integral therewith, but often in such form that the core body is formed separate from the stub shafts, the latter being later secured to the ends of the core body.

In the production of rotors forged from ingots, the ingot is forged to cylindrical shape of desired diameter, with a thorough working of the metal, and, in a preferred form, with the stub shaft extensions reduced from the original ingot from which the core body is forged, the forged mass being of sufficient dimensions to permit machining the body portion and shaft extensions to desired final dimensions with an axial bore of substantial diameter through the body portion of the forging and the shaft extensions. The center boring of the forged mass is particularly desirable for the purpose of removing any slag present as an incident of the pouring of the ingot or forging operation, and it likewise serves to permit detection of

any interior cracks or other defects in the forging. The peripheral winding-receiving slots, usually disposed radially, are machined in the solid forging to the desired dimensions; and these slots likewise serve to uncover cracks and other defects in the forging which might make the latter unsuitable for the purpose contemplated and require rejection of the forging.

As the cross-sectional area and length of the rotors of large size turbo-generators increase, the required forgings become so necessarily large that it becomes very difficult to secure sound forgings free from cracks and other defects. In the first place, the mass of steel is so large that it is difficult to secure a sound ingot from which to make the forging; and it is also difficult and expensive to work the steel sufficiently during the forging operation to secure satisfactory physical characteristics of the final forging. It often happens that two and three steel forgings must be made before obtaining one that is satisfactory for use as the rotor core for a large turbo-generator. And it will be apparent, particularly from the fact that these imperfect forgings are often shipped great distances from the steel mills to the plant where the forging is to be machined and the electrical machine is to be built, and the forging is usually center-bored and machined externally and often a considerable portion of the winding slots are machined before the imperfection or defect in the forging is discovered, that the production of sound forgings satisfactory for use as the rotors of large size turbo-generators becomes an item of tremendous expense.

This problem of producing sound steel forgings for rotors of large size turbo-generators which will safely withstand the stresses incident to operation and be commercially economical has for a long time been a serious problem of designers; and applicant has finally solved it through restricting the diameter of the forging necessary to that required to form only the core body proper without the additional material required for the teeth forming the winding slots, and making the rotor teeth and poles as separate pieces which are later solidly united to the forged core body. The diameter and weight of the forging, and ingot required therefor, being thus sufficiently reduced to greatly simplify and permit much greater facility in working the ingot to the required diameter and desired physical characteristics, much greater assurance is thereby provided of a sound forging for the rotor.

While there have been instances in the prior art where the rotor of a dynamo-electric machine

has been assembled in the form of a core body with separate teeth, usually of the laminated type, secured to the periphery of the core body so as to produce slots for a winding, such prior practice has had for its purpose facilitating the placing of the windings in position in the slots of the core, the winding being readily disposed in position on the core body prior to the placement of all or a certain portion of the teeth. And in spite of these expedients of the prior art, there has been no suggestion of the production of solid forged rotor cores wherein the forged element is of a diameter corresponding to the core body, and solid teeth of the same or different material are separately formed and united to the core body for the purpose of facilitating the production of the core in complete form prior to the disposal of the winding in the slots; and manufacturers and designers have up to the present time been forced to contend with a very unsatisfactory and expensive situation in the matter of production of solid cores for large size dynamo-electric machines, particularly such as are required to operate at high speeds.

As an incident of applicant's solution of this problem, the original expense of producing a sound forged rotor body is greatly reduced, and the cost of material is likewise reduced to the extent of a saving in the cost of material heretofore removed by machining of winding slots in the heretofore customary solid forged core. As an indication of the practical value of the present invention, the necessary weight of the required forging for the rotor core for one machine recently designed by applicant has been reduced by approximately 100,000 pounds, thus bringing the weight and size of the forging to a point where there was little difficulty for the steel mill in producing a sound ingot and a reliable and acceptable forging. In accordance with features of applicant's design of rotor, the individual teeth or pole portions may be of steel or other material best fitted, from the standpoint of strength and magnetic characteristics, for the particular machine. And with the slot teeth and pole portions secured to the rotor in a satisfactory manner as described hereinafter, a mechanically and electrically satisfactory rotor for large machines may be produced at a greatly reduced cost, particularly by reducing the hazard of imperfect forgings and reduction of cost of material and expense of required machining.

It is an object of the present invention to provide an improvement in the production of rotors of dynamo-electric machines of great capacity and capable of satisfactory operation at high speeds.

It is a further object of the present invention to provide an improved design and construction of the rotary element for a dynamo-electric machine of great capacity and capable of satisfactory operation at high speeds, wherein portions forming the winding slots and poles of the rotor are formed separately from and united to a forged core body to produce a unitary core element.

It is a further object of the present invention to provide an improved design and construction of rotary field element for a dynamo-electric machine of great size and capable of satisfactory operation at high speeds, embodying a forged rotor body and teeth formed separately from and of material having different characteristics from the material of the core body and united to the core body.

These and other objects and advantages are attained by the present invention, various novel features of which will be apparent from the description and drawing herein, disclosing an embodiment of the invention, and will be more particularly pointed out in the claims.

In the accompanying drawing:

Fig. 1 is a view in elevation, with parts broken away, of a rotary field element of a dynamo-electric machine embodying features of the present invention;

Fig. 2 is an enlarged vertical sectional view in the plane of the line II—II of Fig. 1;

Fig. 3 is a view similar to Fig. 2, showing a detail in enlarged form;

In the embodiment of the invention disclosed in the drawing, the rotating field element of a large size turbo-generator, here shown as a four pole machine, embodies a core body 6 having integral reduced shaft extensions 7, the core body and shaft being bored throughout, as indicated at 8. The rotor core body is provided at equally spaced points about its periphery with radial slots 9 having their side walls provided with dovetail-like recesses 10.

Mounted in tightly fitting relation in these recesses 9 in the core body are a plurality of tooth elements, the spaces or slots 11 between certain of which teeth being utilized to receive a field energizing winding 12 of conventional design. Those teeth both of whose side walls define winding-receiving slots with parallel walls are of similar shape and indicated at 13; and the inner ends of roots 14 of all the tooth portions have their side walls tapering inwardly and provided with dovetail-like projections 15 fitting tightly in corresponding recesses 10 in the side walls of the radial slots 9, the fit being such as to form a connection which is permanent under normal operating conditions and insures the teeth being held in position at all times against the effect of stresses due to centrifugal force developed in the operation of the machine.

The portion of the core body corresponding to the pole centers and unprovided with winding-receiving slots in the ordinary design of rotary field element is provided with radial slots 9, just as the remainder of the periphery of the core body. As indicated in connection with the particular machine shown in the drawing, this polar portion of the core has two centrally disposed tooth portions 13^a and two additional teeth 13^b, one at each side of the centrally disposed teeth 13^a, these teeth 13^a and 13^b being fitted and held in the corresponding slots 9 of the rotor body in the same manner as the teeth 13. The teeth 13^b are shaped on only one side to provide winding seating slots. And the teeth 13^a and 13^b are so dimensioned as to provide a small air gap, indicated at 16, between inner portions of adjacent teeth and they are recessed at one or both side edges at their outer portions where the magnetic density is low, as indicated at 17, the dimensions of these recesses preferably being such as to insure that the weight of pole teeth 13^a, 13^b is equal to that of each tooth 13 removed from the pole center plus the weight of winding carried by such latter tooth. Through this latter provision, and the fact that the stresses due to centrifugal force on the winding sections are transmitted in equal proportions through the wedges 18 to the two adjacent teeth, all of the stresses, due to centrifugal force, on the several tooth portions throughout the periphery of the core are equalized during operation of the machine; and with all of the

slots 9 equally spaced about the periphery of the core body, a fully balanced field structure may be produced, particularly with the weight of the several wedges 18, 18^a the same.

The winding 12 is held in position in the slots 11 between the teeth by wedges 18, which may be of non-conducting non-magnetic material, held in place through cooperation of projections at the sides of the wedges fitting securely in corresponding recesses in the side walls of the teeth. Adjacent outer portions of the teeth 13^a, 13^b are similarly formed to receive projections at the sides of wedges 18^a which are securely held in position between the teeth. The wedges 18^a may be of the same material as the wedges 18, or preferably of non-magnetic conductive material; and the ends of wedges 18^a may, if desired, be connected by short-circuiting bars or rings at the opposite sides of the core to form close circuit windings of the cage type to assist in maintaining the rotor field element operating in synchronism at all times.

The end turns, indicated at 21, of the winding are held in position by a collar element 23 having a shoulder portion at its inner side cooperating with a correspondingly formed portion at the ends of the teeth of the core, the collar element 23 being secured in position by an annular member 24 suitably positioned and held in place on the rotor body or the shaft extension thereof.

The winding 12 and the wedges 18 between adjacent teeth 13 serve to brace and assist in holding the outer portions of the teeth in normal position, and the wedges 18^a have a corresponding effect with respect to the teeth 13^a, 13^b.

The teeth which lie intermediate those magnetically active tooth portions constituting adjacent field poles, such an intermediate tooth being indicated at 26, may readily be of non-magnetic steel or like material of suitable mechanical strength, for the current in the adjacent winding section at one side of this tooth flows in a direction opposite to that of the current in the adjacent winding section at the other side of such tooth and hence there is no appreciable magnetic flux in the normal direction through the tooth; and with such an arrangement, the reluctance of the leakage path between poles is increased and the field leakage thereby reduced.

In preparing the finished core, the forging is center-bored and machined externally to desired dimensions, and the slots or recesses 9 in rough shape are provided at equally spaced points about the periphery of the core body, these slots being preferably first machined with inclined walls corresponding substantially to the edges of dovetail projections to be formed in the walls of the finished slots. The recesses 10 in the walls of the slots are preferably roughed out, and then the final machining of these recesses is performed to accurately dimension the slots and provide their desired conformation of recessed side walls. As indicated more particularly in Fig. 3, the bottoms of the recesses in the side walls of the slots 9 and in the sides of the root portion 14 of the teeth are of easy curvature, and the dovetail projections on these parts are correspondingly shaped to provide a tight fit between the parts, while at the same time avoiding shapes which might occasion undue concentration of stresses exerted by the root portions on the core body during high speed operation of the rotor.

The teeth 13, 13^a, 13^b may each be formed as single piece, but they are preferably made in sections fitting against one another, as indicated in

Fig. 1, of one foot or more in length, to facilitate machining and handling, particularly in inserting the parts to operative position lengthwise of the core body. The teeth, or the sections forming the same, are preferably of rolled and heat treated alloy steel of high tensile strength and favorable magnetic characteristics, a nickel-steel composition being satisfactory for ordinary purposes. An accurate finishing machine operation, and one of higher grade than can readily be produced on the side walls of teeth integral with a forged core body and formed by machining the winding-receiving slots, can be readily performed on the stock which is to be secured in the slots 9 of the core body to produce a core in accordance with the present invention. And the desired accurate conformation of the root portions 14 of the teeth to cause the latter to fit tightly in slots 9 can be readily produced on the stock from which the teeth are formed.

With the core body machined as to its central bore and outside dimensions, and properly dimensioned and shaped slots 9 provided therein, the core body may be heated, preferably by causing superheated steam to pass through the bore 8 of the core body or by inserting an electric heater within the bore 8, the heating being carried to a point which insures slight enlargement of the peripheral slots 9; and the sections of the tooth portions 13, 13^a, 13^b are then inserted into position, with the roots of these teeth in interlocking engagement with the walls of the slots 9, and the core body is thereafter allowed to cool.

When the assembled core body, with the separately formed teeth secured in position thereon, is cooled to normal or ordinary operating temperatures, the teeth are firmly secured in desired operative position, and they readily maintain themselves in such position against the effect of any stresses due to centrifugal force likely to arise during high speed operation of the machine. The winding is then disposed in conventional manner by radial placement of the coil sides in position in the slots 11 and is secured therein by wedges 18. Due to the fact that a very true and accurate finish may be produced on the side walls of the separately formed teeth prior to attachment of the same to the core body, the winding may be very readily and thoroughly forced into intimate mechanical and heat-transferring engagement with the walls of the slots. This close fit of the winding in intimate heat-transferring engagement with the walls of the slots contributes greatly to operation of the finished rotor with minimum rise in temperature and consequent minimum heat losses in operation. While the winding 12 and wedges 18 are omitted from some of the slots in Fig. 2, it will be understood that all of the slots 11 of the rotor of the machine shown are provided with such winding and wedges. The wedges 18^a are likewise secured in position between teeth 13^a and 13^b, and the end portions of the winding are suitably arranged and secured in position within the collar 23 as described hereinabove.

A rotating field element for dynamo-electric machines, particularly of the turbo-generator type, of great size and capacity and embodying a solid core body of forged steel may be produced in accordance with the present invention wherein all the advantages of the solid, particularly the forged, type of rotor are present, and without the inherently great disadvantage incident to attempting to forge a rotor body of a diameter corresponding to the diameter of the finished rotor

element with the tooth portions forged integral with the rotor body, and with the advantage present of being enabled to select material for the teeth of the various portions of the poles which best insures maximum strength and efficiency with minimum weight of parts.

It will be apparent that the invention claimed is not limited to the details of construction and design shown and described, for obvious modifications within the scope of the appended claims will be apparent to persons skilled in the art.

It is claimed and desired to secure by Letters Patent:

1. A rotor field core for a high speed dynamo-electric machine, comprising a forged steel body, and separately formed solid tooth elements mechanically connected to said core body at the periphery thereof to form portions of the magnetic paths through said core body, a plurality of tooth portions adjacent each pole center of said core being of greater width than tooth portions more remote from the pole center, and said tooth portions more remote from the pole center forming winding-receiving slots.

2. A rotor for a high speed dynamo-electric machine, comprising a forged steel core body, separately formed solid tooth elements in a plurality of longitudinally aligned sections mechanically connected to said core body at the periphery thereof and constituting portions of the magnetic poles of said core, and certain of said tooth elements constituting winding-receiving slots, and a winding secured in said slots, other tooth elements adjacent each pole center of said core each being of substantially the same weight as each of said slot-forming tooth elements plus the weight of said winding carried by said latter tooth element.

3. A rotor for a high speed dynamo-electric machine, comprising a forged steel core body, and separately formed tooth elements mechanically connected to said core body at equally spaced points about the periphery thereof and constituting portions of the magnetic poles of said core, certain of said tooth elements more remote from pole centers forming winding-receiving slots, a plurality of tooth elements adjacent each pole center being of greater width than said slot-forming tooth elements, and each of said tooth elements adjacent the pole center being of substantially the same weight as each of said slot-forming tooth elements plus the weight of winding designed to be carried by said latter tooth element.

4. A rotor for a high speed dynamo-electric machine, comprising a forged steel core body, and separately formed tooth elements mechanically connected to said core body at equally spaced points about the periphery thereof and constituting portions of the magnetic paths of said core, certain of said tooth elements more remote from pole centers forming winding-receiving slots, a plurality of tooth elements adjacent each pole center being of greater width than said slot-forming tooth elements and each being of substantially the same weight as each of said slot-forming tooth elements plus the weight of winding designed to be carried by said latter tooth element, and slot-forming tooth elements disposed intermediate adjacent poles of the core being of lower permeability than adjacent slot-forming tooth elements.

5. A rotary field element for a dynamo-electric machine of relatively great capacity and designed for high speed operation, comprising a core including a forged steel body portion, and separately

formed, radially extending solid tooth elements secured to said core body in interlocking relation therewith, each of the polar portions of said core including two spaced groups of spaced slot-forming tooth elements and a series of tooth elements intermediate said two groups of slot-forming tooth elements and forming an unwound sectional pole center portion, and winding sections disposed in the slots formed by said spaced groups of tooth elements.

6. A rotary field element for a dynamo-electric machine of relatively great capacity and designed for high speed operation, comprising a core including a forged steel body portion, and separately formed, radially extending tooth elements having root portions secured to said core body in interlocking relation therewith, groups of said tooth elements on each side of and remote from pole centers of the core being spaced apart to provide winding slots, pole windings disposed in said slots, each of the polar portions of said core including a series of tooth elements intermediate two groups of slot-forming tooth elements on opposite sides of the pole center and forming a sectional pole center portion, wedges disposed in the outer portion of said slots and retaining said winding in position therein, and non-magnetic bracing wedges disposed in recesses in the radially outer portion of opposing side walls of said tooth elements constituting said pole centers.

7. A rotary field element for a dynamo-electric machine of relatively great capacity and designed for high speed operation, comprising a core including a forged steel body portion, and separately formed, radially extending tooth elements having root portions secured to said core body in interlocking relation therewith, groups of said tooth elements remote from pole centers of the core being spaced apart to provide winding slots, pole windings disposed in said slots, each of the polar portions of said core including a series of tooth elements intermediate two groups of slot-forming tooth elements on opposite sides of the pole center and forming a sectional pole center portion, each of said tooth elements forming the pole centers and the slotted portion of said poles being of such weight that centrifugal forces exerted during operation of the machine on any of said tooth elements due to its own weight and any winding section carried thereby is the same for all of said tooth elements.

8. The method of producing a rotary field element for a high speed dynamo-electric machine of great capacity, which comprises forging a core body from a mass of steel, machining said core body, providing longitudinal slots with undercut side walls in said core body at spaced points about the periphery thereof, providing solid tooth elements having root portions of substantially the same cross-sectional shape and size as undercut portions of the walls of said slots in the core body, securing said tooth elements in permanent position on said core body by heating said core body to a temperature considerably in excess of any normal operating temperature of the machine to expand wall portions of the peripheral slots thereof, and inserting said tooth portions to operative position on said core while the latter is heated with the root portions of said teeth fitting within the undercut slots of the core body, and disposing and securing winding sections in the slots of said core after cooling of the latter.

9. The method of producing a rotary field element for a high speed dynamo-electric machine of great capacity, which comprises forging a core

body from a mass of steel, machining said core body and providing an axial bore therein, machining longitudinal slots with undercut side walls in said core body at equally spaced points about the periphery thereof, providing solid tooth elements having root portions of substantially the same cross-sectional shape and size as undercut portions of the walls of said peripheral slots in the core body, securing said tooth elements in permanent position on said core by applying heat to the axial bore of said core body to raise the temperature of the core body to a value considerably in excess of any operating temperature of the machine to thereby expand wall portions of the peripheral slots of the core body, and inserting the root portions of said tooth elements to operative position in the peripheral slots of said core body while the latter is heated, and disposing and securing winding sections in position in the slots formed between inserted tooth elements after said core body has cooled.

10. A rotor field core for a dynamo-electric machine, comprising a forged steel body, and separately formed solid tooth elements mechanically connected to said core body at equally spaced points about the entire periphery thereof, a portion of said tooth elements adjacent the pole centers of the core being of greater width than tooth elements more remote from the pole centers and said tooth elements more remote from the pole centers forming winding-receiving slots.

11. A rotor field core for a dynamo-electric machine, comprising a forged steel body, and separately formed solid tooth elements mechanically connected to said core body at equally spaced points about the entire periphery thereof, a portion of said tooth elements adjacent the pole centers of the core being of greater width than tooth elements more remote from the pole centers, said tooth elements more remote from the pole centers forming winding-receiving slots, and slot-forming tooth elements disposed at points intermediate adjacent pole centers being of lower

permeability than tooth elements nearer said pole centers.

12. A rotor core for a high speed dynamo-electric machine, comprising a forged steel body, and separately formed solid tooth elements mechanically connected to said core body at the periphery thereof and forming polar portions of the core each comprising a plurality of tooth portions adjacent the pole center and tooth portions at each side of and of less width than the tooth portions adjacent the pole center and forming winding-receiving slots of a width throughout permitting insertion radially therein of formed portions of a winding of substantially the width of the slots.

13. The method of producing a rotor for a high speed dynamo-electric machine of great capacity, which comprises providing longitudinally extending slots with undercut side walls in a core body of forged steel at spaced points about the periphery of said core body, securing in position on said core body solid tooth elements having root portions of substantially the same cross sectional shape and size as said undercut slots in the core body by heating said core body to a temperature substantially in excess of any normal operating temperature of the core body to expand wall portions of the peripheral slots thereof, and inserting said tooth portions to operative position on said core while the latter is heated with the root portions of said teeth fitting within the undercut slots of the core body, and disposing formed winding sections of substantially the width of the slots formed between adjacent tooth portions within said latter slots by placement therein in a substantially radial direction.

FIRST WISCONSIN TRUST COMPANY,
Executor of the Estate of Robert B. Williamson,
Deceased,
 By H. W. GROVE,
Vice President,
 W. I. BARTH,
Secretary.