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[54] DYNAMO ELECTRIC MACHINE CONSTRUCTION

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Jan. 8, 1971 Germany .... P 21 00 663.3

[52] U.S. Cl. 310/67
[51] Int. Cl. H02k 7/00
[58] Field of Search 310/67, 266, 211, 310/182, 261, 264, 265, 62, 63, 91

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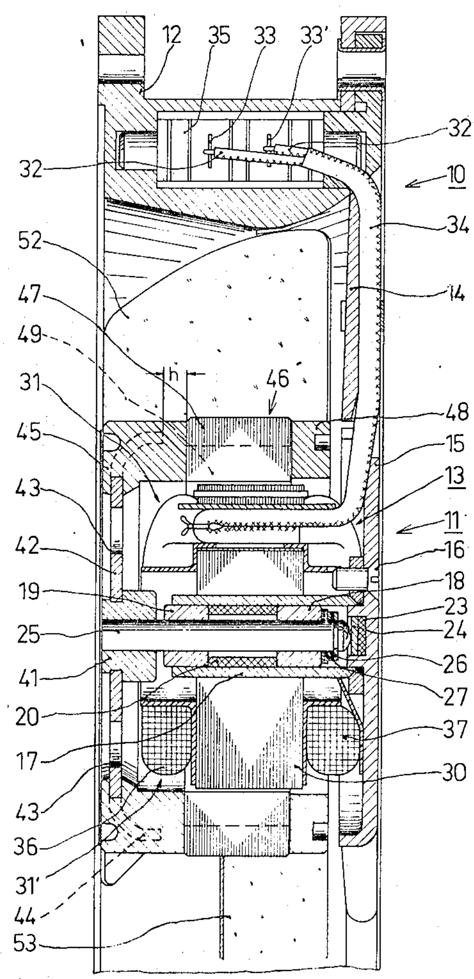
Primary Examiner—R. Skudy
Attorney—Flynn & Frishauf

[57] ABSTRACT

The rotor of a dynamo electric machine, one which is to be supported only at one end, is attached to the shaft by a disk-shaped steel element of circular outline which has outer marginal portions which are cast into the conductor portions of a squirrel cage rotor, the casting being, of aluminum for light weight and high conductivity; in a preferred form, the disk-shaped steel element is dished or bowed, and the marginal portions are bent-over, in contact with the magnetic elements of the rotor, or spaced therefrom by a distance sufficient to leave enough casting material adjacent the motor so that the resistivity of the short-circuited squirrel cage windings will be hardly increased by the presence of the steel element.

24 Claims, 16 Drawing Figures



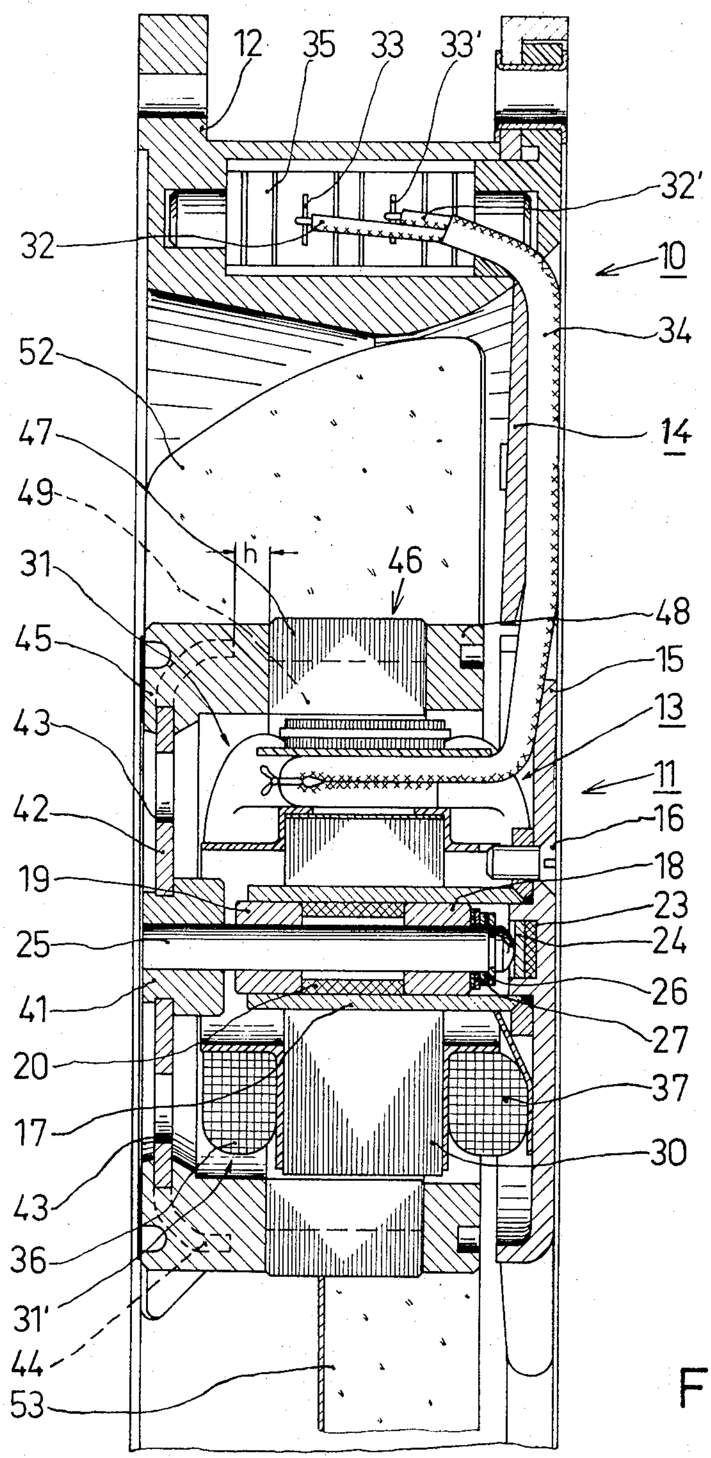

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Fig. 1

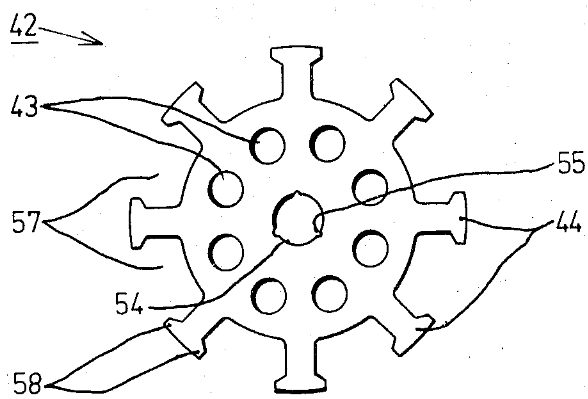

Fig.2

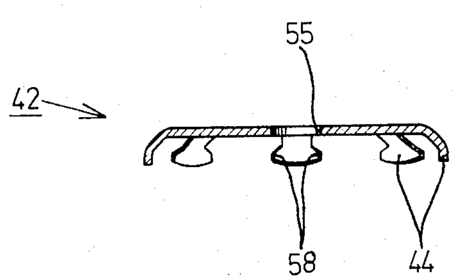

Fig.3

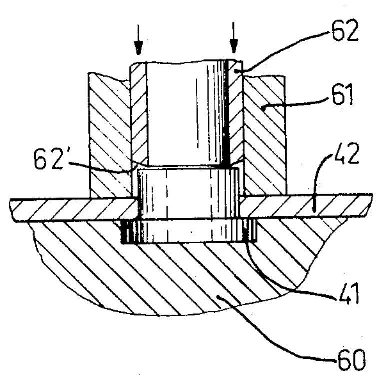

Fig.4

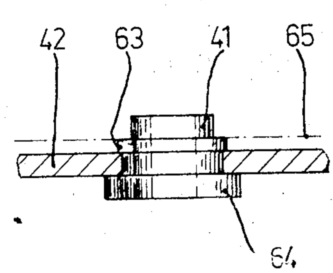

Fig.5

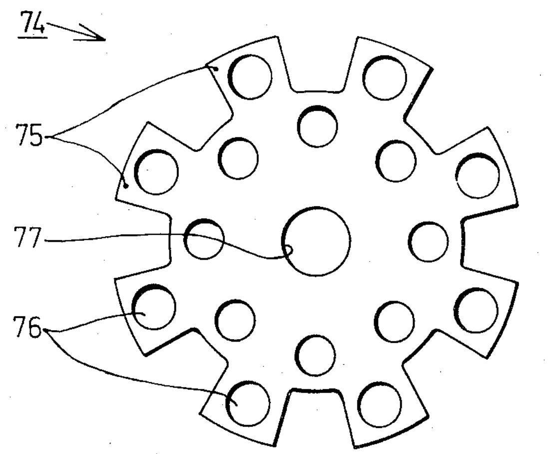

Fig. 6

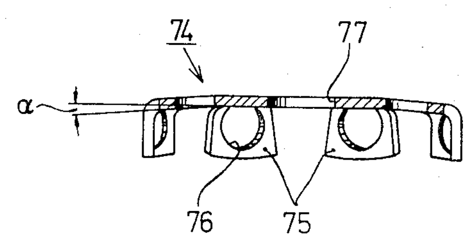

Fig. 7

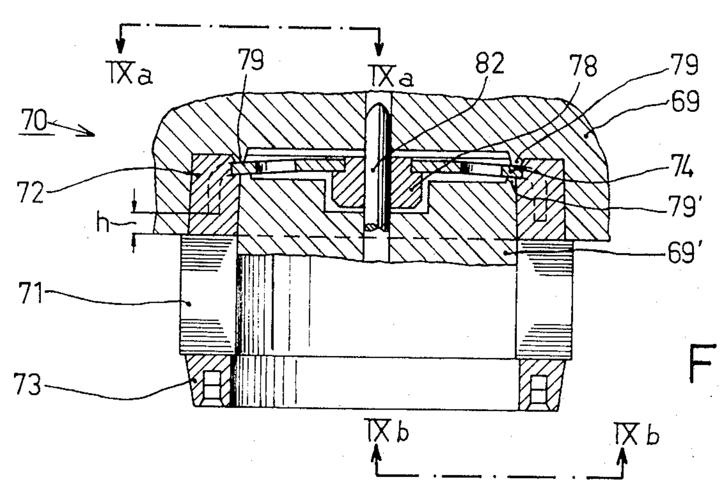

Fig. 8

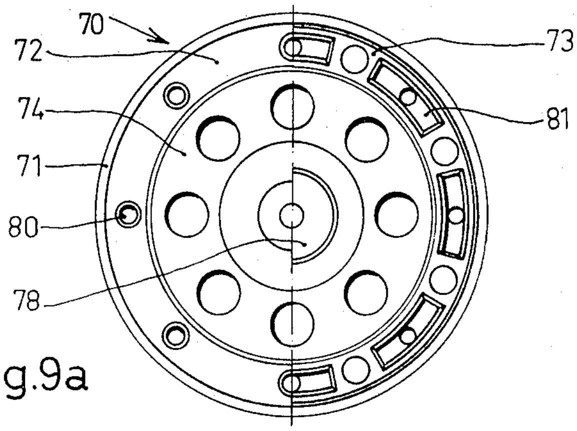

Fig.9a

Fig. 9b

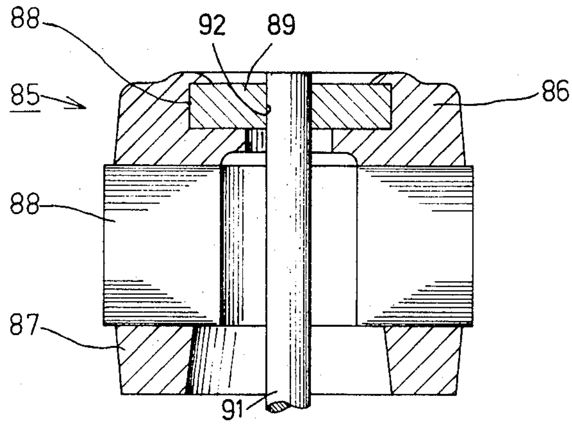

Fig.10

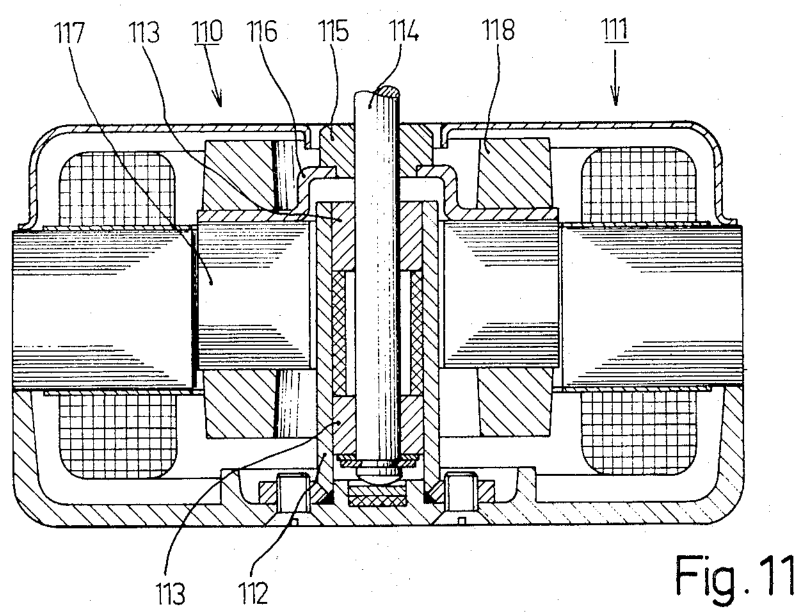

Fig.11

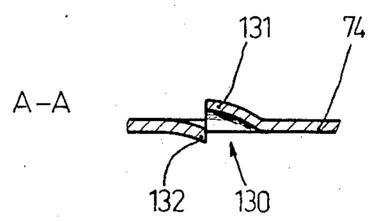

Fig. 12

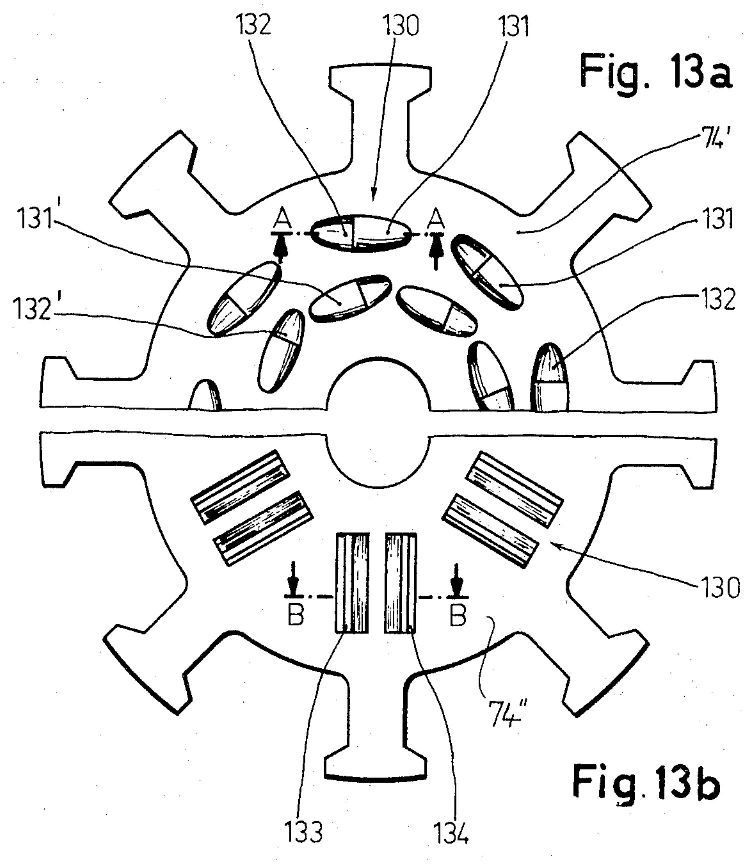

Fig. 13a

Fig. 13b

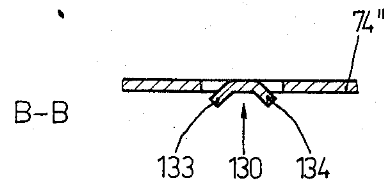

Fig. 14

DYNAMO ELECTRIC MACHINE CONSTRUCTION

The present invention relates to a dynamo electric machine and more particularly to a fractional horse power small appliance-type dynamo electric machine; and specifically to the rotor construction for a motor.

Dynamo electric machines of the fractional horse power type, when used as motors, are widely incorporated in axial ventilators, tape recorders, phonographs and turntables, office machinery and the like. In one construction which is widely used, the rotor is located outside of the stator and it has previously been proposed to make the short circuit cage of the rotor simultaneously in the form of a rotating cover or shell, the cover or shell-rotor combination being assembled with a shaft. The shaft itself is customarily of different material, typically steel, and must be interconnected with the rotor housing which is frequently of different material, that is, material which is easy to machine and has a low electrical resistivity. The interconnection between the shaft of steel and the housing or casting of a different metal is frequently made by casting a shaft bushing into the rotor itself.

Circumferential rotor-type rotors are usually cup-shaped, the shaft of the rotor being secured to the bottom of the cup-shaped rotor element. The walls of the rotor element form the electromagnetically active portion of the motor. The bottom of the cup-shaped element usually is cast from the same material as the squirrel cage and integral with it, and is therefore, for constructional and electrical reasons, usually made of aluminum. In order to reduce the electrical resistance of the cage, the aluminum used is frequently highly purified aluminum. Such highly purified aluminum has poor strength characteristics and therefore the bottom of the rotor cup must be made relatively thick, and in many constructions it is necessary to include stiffening ribs or the like, particularly when the bottom is pierced with ventilation openings or ducts. Increasing the thickness of the bottom of the rotor cup, or particularly using ribs to improve the strength limits the size of the end turn of the windings of the stator, or requires an increase in axial length of the entire motor which is frequently undesirable. It is a difficult foundry procedure to make thin aluminum bottoms in cup-shaped structures. It is also difficult to reliably secure a shaft, or a shaft bushing into the bottom of such a cup-shaped rotor structure, and to provide for long-term secure attachment, and alignment of the shaft under dynamic stresses, as the motor operates. Particularly if the rotor is cast of pure aluminum, alignment and matching of surfaces of the inside of the rotor with the shaft forms a critical point in the entire motor assembly.

The development of motors is directed to decrease their axial length. This is true not only for motors in which the rotor surrounds the stator, but also for motors in which the stator is located outside of the rotor. In a known construction, a central support tube is provided on which bearings are mounted. The rotor is hollow on its inside and secured to a shaft which is inserted about, or within the bearings of the central support tube, to turn therein, or thereover. The rotor thus rotates about the fixed shaft tube and co-acts at its outer surface with the electromagnetic active air gap derived from the stator. The rotating parts of the motor of this type of construction are mechanically similar to the parts of the motor in which the stator is located inside of the motor, so that the same difficulties regarding mechanical attachment of the end shell of the rotor will arise. The axial length of such an interior-type rotor of a dynamo electric machine is less, but it is more expensive than the known construction of internal rotors in which a stack of laminations are secured to the shaft of the machine itself, and in which the shaft is held in bearings fixed to the end bells of the rotor.

It is an object of the present invention to provide a dynamo electric machine which has short axial length and which is inexpensive to make, while providing reliable interconnection of the parts, so that, even in long-term operation, they will not go out of alignment or be subject to damage.

SUBJECT MATTER OF THE PRESENT INVENTION

Briefly, the dynamo electric machine has a stator and a rotor which is rotatable with a shaft with respect to the stator about the axis of the shaft. The rotor is secured to the shaft at least at one end portion thereof, the attachment arrangement including a disk-shaped metal element, typically steel, of essentially circular outline which has its outer marginal portions cast into cast portions of the rotor. The disk-shaped element is preferably dished, or bowed, and the outer marginal portions may be formed with cut-outs to further improve the intimate connection between the cast rotor structure (for example of highly purified aluminum) with the mechanically strong dished end metal element.

The end disk-shaped metal element may bear against the magnetic parts of the rotor structure, or be spaced therefrom by a distance which is selected to leave enough rotor cage material so that the resistivity of the end connections of the rotor is hardly increased over that it would have in the absence of the end portions of the disk-shaped elements, so that the torque is only slightly decreased. In accordance with another embodiment, the end marginal portions are in contact with the magnetic circuit of the rotor, the end cage connections being cast therearound. The shaft can readily be secured to the end disk, preferably before casting of the end plate into the remainder of the rotor structure, by locating a shaft in a centered cut-out which is partly non-circular, and upsetting a shaft against the originally non-circular opening so that material will flow therebetween, thus forming a reliable tight and secure connection which will not permit relative rotation of the shaft and the rotor structure when finally assembled.

The invention will be described by way of example with reference to the accompanying drawings, wherein:

FIG. 1 is a vertical cross-sectional view through a motor structure having an outer rotating rotor, integrally connected with the blades of an axial ventilator; the lower half of FIG. 1 is in a section which is rotated by an angle of 90° with respect to the section of the upper half;

FIG. 2 is a plan view of an end blank of the rotor end unit;

FIG. 3 is a transverse cross-sectional view of the end blank of FIG. 2, after the marginal portions are bent;

FIG. 4 is a detail view, to an enlarged scale, illustrating one step in the operation of securing a bushing to the end disk;

FIG. 5 is a tranverse cross-sectional fragmentary view of the shaft bushing after the next step of the attachment operation, part of which is illustrated in FIG. 4;

FIG. 6 is a plan view of another embodiment of an end disk;

FIG. 7 is a transverse sectional view of the disk of FIG. 6 after bending;

FIG. 8 is a longitudinal sectional fragmentary view of an external rotor utilizing the end disk of FIG. 7 and cast into the rotor;

FIG. 9*a* is a top view, and FIG. 9*b* a bottom view of the rotor of FIG. 8, seen along lines IX*a*—IX*a* and IX*b*—IX*b*, respectively, of FIG. 8;

FIG. 10 is a longitudinal cross-sectional view of a rotor to rotate within a stator;

FIG. 11 is a schematic cross-sectional view of an inside-rotating dynamo electric machine, illustrating interconnection of shaft and rotor;

FIG. 12 is a cross section along line A—A of FIG. 13*a*;

FIG. 13*a* is a plan view of half of an end disk illustrating additional air supply to the rotor;

FIG. 13*b* is a plan view similar to FIG. 13*a* illustrating a different embodiment; and

FIG. 14 is a transverse fragmentary cross-sectional view along lines B—B of FIG. 13*b*.

In the specification which follows, with reference to the drawings, the terms "right" and "left" refer to the illustration of the drawings. Like parts in the various embodiments will be described but once and have been given the same reference numerals.

The external rotor motor **11** of the fan or ventilator **10** of FIG. **1** has an outer housing **12** which is essentially a single cast or extruded unit. A flange **14** to which a mounting plate **15** is secured is secured to one face plate of housing **12.**

Screws **16,** of which only one is shown, secure a bearing tube **17** to mounting plate **15.** Stator **13** of motor **11** is secured to the bearing tube **17.** The interior of the bearing tube includes a pair of journal bearings **18, 19,** of sintered or similar porous material, having a felt element **20** therebetween to supply lubricant to the bearings. A pair of disks **24** are secured in a recess **23** of plate **15,** to form a first thrust bearing for a shaft **25.** Shaft **25** has a groove formed at its left end into which a C-ring **26** is snapped, holding four disks **27,** forming with the right face of bearing **18** a second thrust bearing for shaft **25** to secure the shaft **25** in axial position. Thus, shaft **25** is held by the two thrust bearings **24** and **18, 27,** in a predetermined position, axially, the two bearings **18, 19** serving as radial guides for shaft **25.**

A stator stack of laminations **30** is secured to the carrier tube **17,** windings **31** and **31'** being inserted into the stator in known manner. Electrical connections **32, 32',** carried through an insulating tube **34** are connected to a terminal plate **35** secured to the housing unit **12,** and on which a pair of connecting contacts **33, 33'** are provided to interconnect with the conductors **32, 32'.** Windings **31, 31'** have end loops **36, 37.**

Shaft **25** has a bushing **41** thereon, preferably formed as a machine part and made of steel. Bushing **41** is non-rotatably secured to shaft **25.** A disk-shaped plate **42** is non-rotatably secured to bushing **41.** Disk **42** is formed with eight openings **43** (FIG. **2**) to permit air to pass therethrough. The outer marginal portions are formed as extending ribs **44** which are cast into the left short circuit ring **45** of the outer rotor housing **46,** forming the outer portion of the motor. The outer portion **46** additionally has a rotor lamination stack **47** and a right short circuit ring **48.** The short circuit rings **45, 48** are interconnected by rods **49,** cast into grooves formed in the lamination stack **47,** rods **49** and short circuit rings **45, 48** forming a complete squirrel cage rotor. The material of the electrical conductor portion thereof, that is, the cast material can be aluminum, preferably purified aluminum and, in one form, highly purified aluminum of minimum electrical resistivity. The disk **42** is of strong metal, preferably steel.

Fan blades are welded to the external rotor **46,** of which two are shown at **52, 53.**

The end disk **42** is best seen in FIGS. **2** and **3.** A flat, circular disk is punched to have the shape shown in FIG. **2.** A central opening **54** is formed therein which has noncircular contours, that is, the central opening is formed with three outwardly extending notches **55,** offset from each other by 120°, and which will be discussed below in greater detail. The marginal portions have cut-outs **57** punched therein so shaped that the remaining ribs **44** at their free ends have T-shaped enlargments **58.** When the end disk **42** is cast into the rotor, an excellent interconnection is provided which is reliable in operation and sturdy in use, particularly, if the end marginal portions **44** are bent over, as best seen in FIG. **3,** at approximately right angle to the major plane of the element **42.** As seen in FIG. **1,** the diameter of the marginal portions **44** is so selected that they come close to the outer circumference of the short-circuit ring **45.** During casting, they are so located that the distance between the ends of the lamination stack **47** and that of the ends of portions **44** shown as "*h*" in FIG. **1,** is as large as possible consistent with design dimensions. These two criteria, large diameter and largest possible distance of "*h*" contribute to reduction of the resistance of the short circuit ring **45** which otherwise would be increased by the presence of the marginal portions **44.** The increase in resistance due to marginal portions **44,** of much higher resistivity material, typically steel, than the aluminum of short circuit ring **45,** should result in only minor decrease of the torque delivered by the motor with respect to a motor which would not have the marginal portions **44** cast therein. Experiments and actual tests have shown that the decrease in torque due to the presence of cast-in marginal steel portions is negligible, and is within the statistical field of torque values encountered in a series of such motors, if the distance "*h*" and the diameter of the marginal portions **44** are selected to be as large as possible.

Shaft **25** and bushing **41** should be securely interconnected, and have long operating life. Various interconnections can be used. In one example, bushing **41** can be welded to the disk **42,** particularly by pulse welding, or by brazing, for example by induction brazing. A particularly simple interconnection, suitable for an end disk as seen in FIGS. **2** and **3,** and formed with notches **55,** is illustrated in connection with FIGS. **4** and **5.**

Disk **42,** with a bushing **41** of raw blank form as seen in FIG. **4** is inserted into a jig **60.** A hold-down tool **61** is placed against the disk **42,** to securely hold disk **42** and bushing **41** together. Compressive force is applied in the direction of the arrows in FIG. **4** against a cylindrical punch **62.** Punch **62** has a work face **62'** which is slightly conical, and punch **62** thus will deform the outer circumference of bushing **41** to result in the final shape shown in FIG. **5,** forming a holding ring **63** and simultaneously flowing the material of bushing **41** into the notches **55** (FIG. **2**) in order to provide a stable, sturdy non-rotating connection between disk 42 and bushing 41. The lower edge 64 of bushing 41 bears against the disk 42 and is countered at the other side by the ring 63, thus forming a connection which is not subject to change in orientation even under substantial dynamic stressing. If necessary, the bushing can be machined along the chain-dotted line 65, by cutting off the excess portion, to result in bushing 41 as seen in FIG. 1, of minimum axial length. This interconnection is suitable for any one of the embodiments of the rotor shaft described herein.

FIG. 8 illustrates a rotor 70 for a circumferential-rotor type dynamo electric machine, which could be used instead of rotor 46 in the motor of FIG. 1. Rotor 70 includes a lamination stack 71, with a cast short circuit squirrel cage, for example of pure aluminum. An upper short circuit ring 72 and a lower short circuit ring 73 are shown, interconnected by connecting bars which are placed in grooves (not shown) of lamination stack 71. FIG. 8 illustrates a casting apparatus to cast the end plate into the stator assembly. Circumferential edges 79, 79' of a casting apparatus 69, 69' are illustrated in the position ready for casting. In this position, the edges 79, 79' are pressed against the end plate 74 with sufficient force that they will form a shallow groove in the end disk 74, for example to the extent of 1/10 mm. This slight groove, coupled with the pressure of application provides a secure and tight connection against rotor short circuit material, even if introduced by pressure casting. The surfaces of the disk 74 will then have a pair of ring-like depressed zones, of shallow depth, which additionally contribute to stiffening of the end disk.

The end disk 74 is secured to the upper short circuit cage 72, by casting its marginal portion into the ring 72 forming the short circuit cage. Again, the distance between the ends of the marginal portion of disk 74 and lamination stack 71 is "*h*," this space being completely filled by cast material of the end ring of the cage, in order to decrease the internal resistance of the end ring as much as possible. FIG. 6 illustrates the punched disk before profile formation, and flat, as it would come from a punch. The disk of FIG. 6 is then shaped to have the form of FIG. 7, with the marginal portions 75 bent over. Holes 76 are punched into the marginal portion to provide for good and intimate interconnection of the end disk with the short circuit ring 72. During bending of the marginal portions 75, the disk 74 is slightly bowed, as illustrated in FIG. 7 by angle α. This additionally contributes to stiffness of the disk 74. A bushing 78 is inserted into a central opening 77 for interconnection with a shaft, not shown in FIG. 8. This bushing 77 may again be inserted, by means of circumferential notches (not shown), similar to that described in connection with FIGS. 4 and 5, or welded or brazed, as desired.

The pressure casting dies 69, 69', with their circumferential pressure edges 79, 79' hold the disk 74 with such force that a sufficient deformation occurs at the surface of the disk. This effectively prevents undesired thin flash projections, or undesired material at the surface of disk 74. Pin 82 of the tool centers the disk 74 during casting. The slight deformation of the disk, particularly in combination with previous bowing thereof, effectively stabilizes the shape and orientation of the disk with respect to the rotor after final casting.

FIG. 9*a* is a view of the rotor 70 of FIG. 8 from above. FIG. 9*b* is a view of the same rotor from below. Holes 80 (FIG. 9*a*) and holes 87 (FIG. 9*b*) are provided to permit balancing of the rotor.

FIG. 10 illustrates a rotor 85 which is intended to operate within a stator. Rotor 85 again is a squirrel cage rotor, with an upper short circuit ring 86, a lower short circuit ring 87 and connecting bars (not shown) cast into a rotor lamination stack 88. The upper ring 86 has a disk-shaped member 89 cast therein which, again, is a punched disk. The inner opening 92 of disk 89 has shaft 91 press-fitted therein. The punched disk 89 should be punched with an accurate highly reliable tool, which has a very small cutting gap, so that the cut surface will be true to size over the entire thickness of the punched part, and does not show burrs or broken-away zones of excessive tolerance. If disk 89 is accurately punched, shaft 91 can be press-fitted by means of an interference fit directly, or can be interconnected by means of upsetting, without an additional bushing.

FIG. 11 illustrates, schematically, a rotor construction particularly suitable for a rotor running within a stator, and enabling use of a particularly long bearing tube. Rotor 110 thus rotates within stator 111. A stationary bearing tube 112 is located in the interior of rotor 110, constructed similarly to bearing tube 17 in accordance with FIG. 1. Bearing tube 112 has a pair of self-lubricating bearings 113 associated therewith, and shaft 114 rotates within the bearings. The upper end of shaft 114 has a bushing 115 secured thereto. A hat-shaped, upset sheet metal disk 116 is secured to bushing 115. The attachment is at a center, convex portion. The outer marginal portions of the sheet metal element 116 bears directly against the lamination stack 117 of rotor 110, and is secured to the rotor 110 by casting into the upper short circuit ring 118. Thus, the end disk 116, in this construction, forms one lamination of the lamination stack of the rotor 110.

The disk-shaped element 74' of FIGS. 12–14 is similar to that of element 74 of FIGS. 8, 9*a*, 9*b*. In addition to the openings formed therein, projections and depressions 130 are formed in the disk-shaped element 74', in order to increase the amount of cooling air supplied to the interior of the motor, when the disk rotates during operation of the motor. The projections and depressions 131, 132, as seen in FIGS. 12 and 13*a*, are bent towards both sides of the element 74, and are arranged in two circumferential rings 131, 132 and 131', 132', oriented reversely with respect to each other so that air will be supplied regardless of direction of rotation of the rotor. A similar arrangement is shown in FIG. 13*b*, where disk 74'' has flags 133, 134 punched out, the flags 133, 134 being of greater radial width and so arranged that they will supply air to the interior of the rotor regardless of direction of rotation of the motor.

Rotors, and particularly short circuit rotors of fractional horse power motors can readily be interconnected with associated shafts by practicing the invention as disclosed. The shafts of these rotors will be securely and reliably connected and will be in alignment with the rotors, even after long periods of operation. The axial length of the motor can be reduced. The casting operation itself is simple and presents less difficulties and does not require any special tools or fixtures.

Various changes and modifications may be made within the inventive concept.

We claim:

1. External rotor dynamo electric machine having a support,

a central stator fixed in the support,

a shaft,

an external rotor rotatable with the shaft with respect to the stator about the axis of the shaft, said rotor surrounding the stator and having a magnetic circuit, axially extending conductor portions and short circuit rings located at the ends of the axially extending conductors, the short circuit rings comprising good electrically conductive metal integrally connected to the axially extending portions and forming therewith an external squirrel cage rotor;

and means securing the external squirrel cage rotor and the shaft for joint rotation together at one end portion of the rotor, said means comprising

a disk-shaped sheet metal element of structurally strong material and of essentially circular outline extending diametrically of the motor, said element being centrally secured to the shaft and having outer marginal portions formed with projecting portions the projecting portions extending in axial direction and being cast into and integrally secured within one of the electrically conductive short circuit rings of the rotor.

2. Machine according to claim 1, wherein the disk-shaped element is concavely bowed.

3. Machine according to claim 1, wherein the disk-shaped element is a punched sheet metal disk.

4. Machine according to claim 1, wherein the outer marginal portions of the sheet metal element are formed with radial cut-outs, the remaining metal of the outer marginal portions forming projecting ribs, said ribs being cast into the adjacent short circuit ring of the rotor.

5. Machine according to claim 4, wherein the ribs are, in plan view, essentially T-shaped, and are formed with circumferentially extending bulges.

6. Machine according to claim 1, wherein the short circuit rings comprise high conductivity aluminum and the projecting portions are ribs cast into the adjacent short circuit ring of the rotor.

7. Machine according to claim 1, wherein the axially extending marginal portions form projecting ribs which are speced from the magnetic circuit of the rotor by a distance (h) determined by the current flow in the short circuit rings, said distance (h) being selected to introduce additional resistance into the short circuit rings which is small with respect to the resistance of the rings without the marginal portions to minimize power loss of the machine.

8. Machine according to claim 1, wherein the marginal portions of the disk-shaped elements are mechanically connected with the magnetic circuit of the rotor and form a portion of the rotor stack and are secured thereto by the conductor material of the rotor.

9. Machine according to claim 1, wherein the disk-shaped element has axially extending end portions to form a cup-shaped element.

10. Machine according to claim 1, wherein the disk-shaped element has a central cylindrical projection, the central projection being connected with the shaft.

11. Machine according to claim 1, wherein the disk-shaped element has a central opening which has portions which are non-circular;

a bushing pressed into the central opening and being deformed such that the material of the bushing flows in the non-circular portions to form a non-rotatable connection between the bushing and the sheet metal element.

12. Machine according to claim 1, wherein the sheet metal element has a central opening;

a bushing secured in the central opening, the bushing being welded to the sheet metal element.

13. Machine according to claim 1, wherein the sheet metal element is formed with a central opening; a bushing inserted into the central opening, the bushing being brazed to the central opening.

14. Machine according to claim 1, wherein the sheet metal element is a precision punched part having a central opening punched therein, the central opening being held to accurate tolerance throughout the thickness of the sheet metal element;

the shaft being press-fitted into said central opening.

15. Machine according to claim 1, wherein the sheet metal element is formed, along its face, with projecting fins punched from the plane of the sheet metal element to provide openings through the sheet metal element and air scoops for ventilation of the interior of the rotor.

16. Machine according to claim 16, wherein the punched fins are located on concentric circles of the sheet metal element, selected fins projecting in opposite directions to provide air scoops for the interior of the motor regardless of direction of rotation of the rotor.

17. Machine according to claim 1, wherein the sheet metal element is deformed by circumferential shallow rings extending concentrically with the shaft into the plane of the sheet metal element.

18. Motor according to claim 1, wherein the disk-shaped sheet metal element is of steel.

19. Fractional horse power motor having a shaft, a stator surrounding the shaft windings surrounding the stator, and an external squirrel cage rotor surrounding the stator and having an electromagnetic portion comprising axial conductor bars and integrally connected short circuit end rings comprising a material of good electrical conductivity but of low mechanical strength, and stacks of magnetic laminations being cast between the short circuit end rings;

and a sheet metal disk of a material of high mechanical strength and an electrical conductivity which is low with respect to that of the conductor end rings and bars, formed with a central opening, the shaft being secured to the central opening, transversely of the disk with an interference fit to locate the disk adjacent an end portion of the stator;

the sheet metal disk having axially extending projecting marginal portions which are cast into and integrally secured into the adjacent short circuit end ring to secure the electromagnetic portion of the rotor directly to the shaft and form a unitary, integral rotor-shaft assembly which can rotate about the stator.

20. Motor according to claim 19, wherein the end rings and conductor bars are aluminum.

21. Motor according to claim 19, wherein the sheet metal disk is steel.

22. Motor according to claim 19, wherein the marginal portions of the sheet metal disk are perforated

and the regions of marginal portions beyond the perforations are cast into the rotor-shaft assembly.

23. Motor according to claim 19, wherein the central opening of the shaft, at least in part, is noncircular; a bushing press-fitted into the opening and having bushing material flowed into the non-circular portions of the opening;

the bushing being secured to said shaft.

24. Machine according to claim 9, wherein the outer marginal portions of the disk-shaped sheet metal element comprise radially extending end portions joined to the axially extending portions, the radially extending portions being connected with the magnetic circuit of the rotor.

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