United States Patent

[11] **3,588,557**

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[21] Appl. No. **800,400**
[22] Filed **Feb. 19, 1969**
[45] Patented **June 28, 1971**
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[54] **LOW LOSS VENTILATION FOR SALIENT POLE MACHINES**
3 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **310/60,** 310/269, 310/61
[51] **Int. Cl.** **H02k 9/00**
[50] **Field of Search** .... 310/55—64, 86, 269, 180, 194

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ABSTRACT: A ventilation arrangement for a dynamoelectric machine having a rotor including salient pole members. Structure is provided for substantially increasing cooling efficiency and reducing windage looses in the machine, the structure comprising means for directing a cooling gaseous fluid axially of the rotor between the salient poles from one end of the rotor to the other, and means for bridging the interpolar space in order to prevent a vortex of the fluid from developing between adjacent poles, and for otherwise restricting the cross-sectional area for axial flow of the cooling fluid to increase the axial velocity thereof.

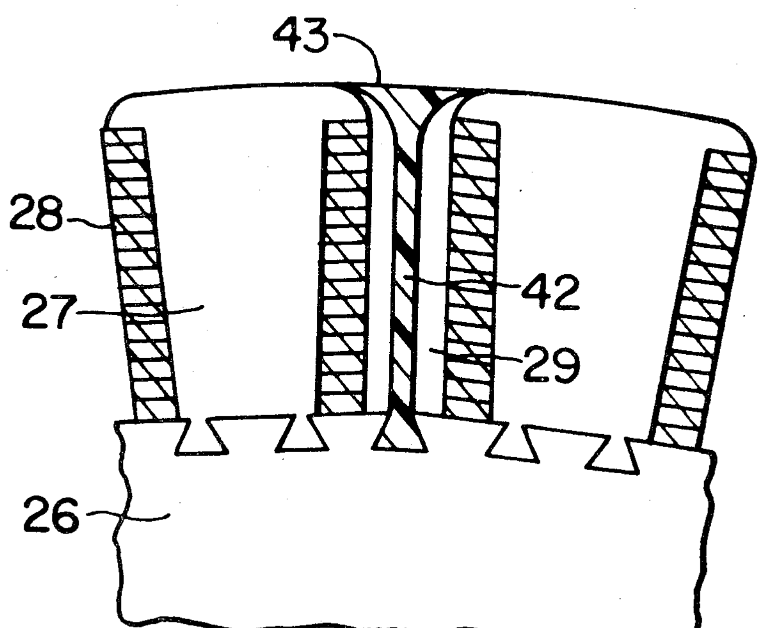

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FIG. 1.

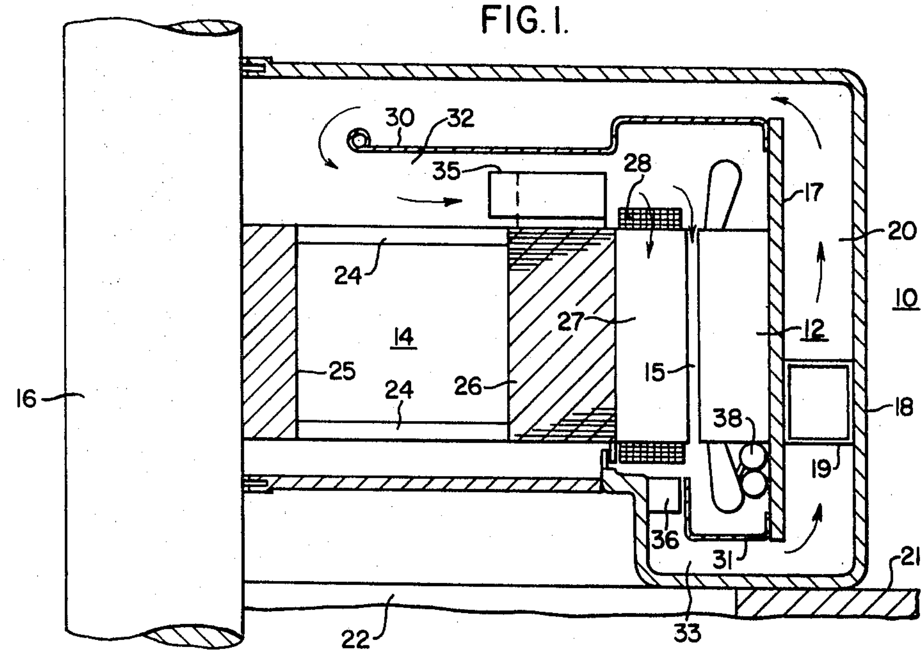


FIG. 2.

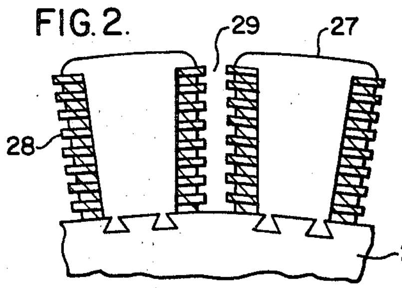


FIG. 3.

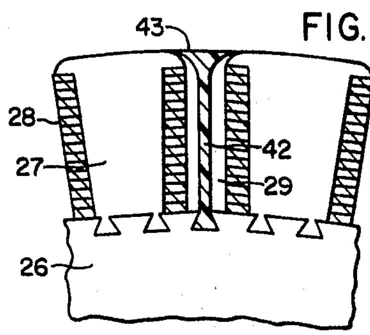


FIG. 6.

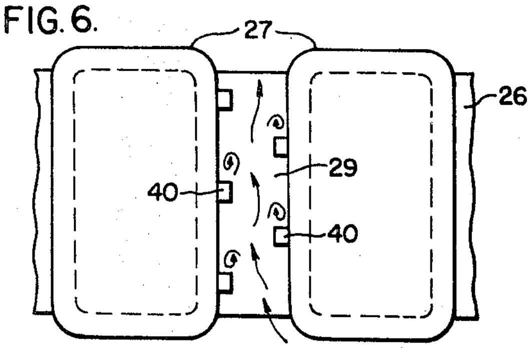
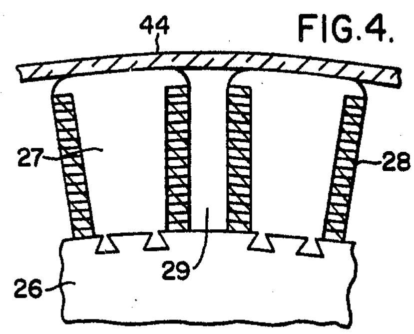


FIG. 4.



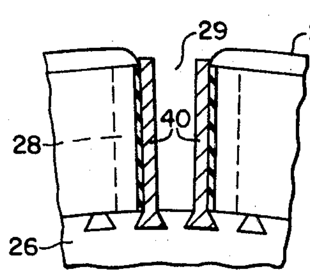


FIG. 5.

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LOW LOSS VENTILATION FOR SALIENT POLE MACHINES

BACKGROUND OF THE INVENTION

The present invention relates generally to the ventilation of dynamoelectric machines, and particularly to low windage loss ventilation in waterwheel generators operable at relatively high peripheral speeds, though the invention is not limited thereto.

Heretofore, it has been the practice in large waterwheel generators and in certain motors with high peripheral speeds of rotation to direct all ventilating air through the rotor from both ends simultaneously towards the center thereof, and discharging the air through radially extending vents or openings provided in the stator. Such a ventilating means results in excessively high windage losses.

For example, if the normal peripheral speed of the rotor is 60 meters per second (11,600 feet per minute) and sufficient air is directed through the machine to provide a limit of 18° C. rise in air temperature, the power required to simply accelerate the air to full speed, and with no blower loss, is 10 percent of the total losses in the machine. If the speed is 85 meters per second, this loss increases to 20 percent of the total loss.

In addition to the above loss, there is a sizable component of windage loss resulting from the relative velocity of the pole members with respect to the surrounding air which creates vortices of air between adjacent poles. Such vortices consume considerable amounts of energy within the machine.

Another method of cooling a machine rotor is by use of pressurized water, or other liquid coolants under pressure, directed through channels or conduits provided in the rotor. Liquid cooling is highly effective. However, liquid cooled rotors required difficult and costly connecting structures for placing the rotating components, i.e. those components associated with the rotor, in liquid communication with stationary components, i.e. pumps and heat exchange apparatus, for example, located at fixed locations with respect to the rotor.

BRIEF SUMMARY OF THE INVENTION

Broadly, in the present invention, cooling air or other cooling gas, is directed past salient pole members of a machine rotor from one end thereof directly to the other, the area between the poles being reduced and/or separated from the airgap between the rotor and stator, the reduced area being effective to increase the velocity of airflow therethrough, and the separated area being effective to prevent the creation of vortices therein. In this manner windage losses in the machine are substantially reduced while simultaneously permitting maximum kva. per pound of rotor material comparable to that obtained with water cooled rotors.

An axial or centrifugal flow blower means is employed to pressurize the cooling air, and stationary diffusing vanes or blades, or a vaneless diffuser, is employed to convert the rotational component of air leaving the poles to pressure energy for return of the air to the blower in a closed loop arrangement. The diffusing function of the vanes or vaneless diffuser generates additional pressure which lowers the pressure (and thus the work) requirement of the blower means.

With these and other measures, as explained hereinafter, the windage loss in a large rotating machine can be reduced to one-third which amounts to a reduction of 25 percent of the total losses in the machine and a possible five-tenth percent (0.5 percent) increase in machine efficiency. This could, in certain cases, result in an evaluated cost reduction of 25 percent.

THE DRAWINGS

The invention, with its advantages and objectives will be more apparent upon consideration of the following detailed description in connection with the accompanying drawings in which:

FIG. 1 shows a radial section of a vertically mounted machine constructed in accordance with the principles of the invention;

FIG. 2 is a partial top elevation view of the rotor of the machine of FIG. 1;

FIGS. 3, 4 and 5 are partial top elevation views of three additional embodiments of the invention; and

FIG. 6 is a partial plan view of the embodiment of FIG. 5.

PREFERRED EMBODIMENTS

Specifically, there is shown in FIG. 1 a radial section of a vertically disposed dynamoelectric machine 10 comprising a stator structure 12 surrounding a rotor structure 14 which form an air gap 15 therebetween. The rotor is suitably attached to a rotatable shaft 16. The stator is attached to a stator frame 17 disposed within a housing structure 18, the frame being attached thereto by a tubular structure and cooler 19 to form a passageway 20 between the frame and housing. The housing in turn, rests on a foundation 21 surrounding a pit 22 wherein a fluid or water turbine (not shown) is suitably located for driving the rotor via the shaft 16.

The rotor 10 includes a structural framework in the form of a spider structure 24 extending between a hub member 25 and a rim member 26, said members being suitably attached to the spider. The hub member is further keyed or otherwise suitably engaged to the shaft 16.

The rim 26 supports a plurality of radially disposed salient pole pieces 27 each, in turn, supporting a field winding 28 wound about the shank portion thereof to form field pole members which extend along the axis of the rotor as seen in FIG. 1. The pole members are circumferentially spaced to provide interpolar spaces 29 (FIG. 2).

The machine 10 is provided with partitions 30 and 31 which form respectively annular, planar inlet and outlet ducts 32 and 33 for directing cooling fluid to and from the poles 28 in the manner explained hereinafter. As shown in FIG. 1, the partitions are attached to the stator frame 17, and are placed in fluid communication with each other by the space and passageway 20 provided between the frame 17 and the housing 18.

A blower structure 35 is provided in the inlet duct 32, the blower being only representatively shown in FIG. 1, The blower may be of the axial flow type using turbine-type blades, for example as shown in U.S. Pat. No. 3,110,827 issued to R. A. Baudry on Nov. 12, 1963 or, the centrifugal type using a circumferential array of axially extending blades in the manner shown, for example in U.S. Pat. No. 3,271,607 issued to Slotnick and Latham on Sept. 6, 1966. (The Baudry, Slotnick-Latham patents are assigned to the present assignee.) In place thereof, or in addition thereto, the spider arms 24 may also be constructed to serve as a sufficiently powerful centrifugal blower in the machine.

The machine 10 is further provided with an annular array of curved, stationary vanes 36 located at the discharge end of the pole members 27, only one vane being visible in the view of FIG. 1. The vanes are curved and pitched to collect and redirect the rotational component of the air, caused by the rotation of the rotor 14, into the outlet duct 33 for return to the inlet duct 32 and blower 35. The vanes function as a diffuser in the duct 33. The duct 33 itself may be positioned and formed to collect and diffuse the air entering from the poles 27 in the manner of a vaneless diffuser which would thus render the vanes 36 unnecessary.

In operation, the poles 27 and the windings 28 of the rotor 14 are effectively and efficiently cooled (i.e. with very low windage losses) in the following manner. With rotation of the rotor, the blower structure 35 pressurizes the air, or other suitable cooling gas within the housing 18, to direct it through the interpolar spaces 29 and through the airgap 15 from one end of the poles 27 to the other end, i.e., in one direction as indicated by appropriate arrows in FIG. 1. The air exits at the outlet end of the poles adjacent the vanes 36 and duct 33, and is directed through the cooler 19 where the heat acquired by the cooling air is removed from the machine. From the cooler, the air is returned to the blower 35.

With rotation of the poles 27 and their high peripheral speeds past the stationary vanes 36 and duct 33, the cooling air directed through the pole spaces 29 and has a high velocity rotational component, i.e., the cooling air tends to rotate with the rotating rotor 14. Without some means to recover the energy in this air the energy is lost to the cooling operation as thus described.

For this reason, the invention includes the vane structure 36 briefly described above. The vanes are pitched and disposed in the duct 33 to collect and convert the rotational component of the air to pressure energy, by the above-described diffusing function, for return of the air to the inlet duct 32 via the intermediate passageway 20. In this manner, the pressure addition provided by the vanes (or the above-mentioned vaneless diffuser) lessens the pressure and thus he the work requirement of the blower 25 thereby permitting a smaller blower structure. Thus the vanes perform the necessary function of collecting and redirecting the rotating air as well as effecting a reduction in the size of the blower.

In the machine 10, as thus far describe, the stator 12 may be cooled by a direct cooling liquid system, for example, as disclosed in the above-mentioned Baudry patent. In FIG. 1, stator end turn connections 38, only diagrammatically shown, represent a part of such a liquid cooled system though the invention is not limited thereto. Obviously, air or other gaseous cooling system could be employed to cool the stator winding.

If the stator winding 12 is cooled by a separate cooling arrangement, for example, by the liquid cooled system described briefly above, it is necessary only to direct sufficient air through the interpolar spaces 29 to remove the heat generated by the field coils 28 and the surface losses of the iron in the poles. These losses typically amount to only 10 to 20 percent of the total loss in the machine. Thus, only 20 percent of the normal volume of cooling air is required. If this 20 percent volume is directed straight through interpolar spaces having the normal and average width dimensions, the axial velocity of the air will be approximately 80 percent of the normal average axial velocity.

In the present disclosure however, the width dimension and cross-sectional area between adjacent poles is reduced, thereby reducing and restricting the total axial area or space 29 between adjacent poles. This restriction of the interpolar space increases the velocity of the cooling air moving axially therethrough to a value of over 100 percent of normal to obtain at least normal cooling of the poles. This restriction of interpolar space is accomplished in the embodiment of FIG. 2 by having alternate turns of the winding 28 extend into the interpolar space 29 beyond the edges of the pole tip overhang.

The interpolar spaces may also be reduced by making the pole pieces 27 wider, or by introducing coil braces 40, as shown in FIGS. 5 and 6, for machines having relatively high speeds of rotation. The braces are secured to the rim 26, and are disposed tightly against the turns of the windings 28.

As seen in the view of FIG. 6, the braces may be alternately disposed along the edges of the coil turns in the interpolar space. The airflow past the braces is indicated by appropriate arrows. In tests conducted using the alternate disposition of the braces, maximum airflow was obtained with adequate air turbulence to effect good heat transfer in the interpolar regions.

In addition to the embodiments and structures described above which lower substantially windage losses and increase the efficiency of heat transfer in the rotor 14, the present invention reduces further the windage losses in the rotor by bridging or banding the interpolar spaces 29 as shown in FIGS. 3 and 4 respectively.

With rotation of the rotor 14, and without some means to separate the interpolar spaces 29 from the airgap 15, the relative velocity of the poles 27 with respect to the air traveling axially through the air gap creates vortices of air between the poles which consume considerable amounts of energy within the machine. This problem is solved or at least substantially mitigated by the structure shown in FIGS. 3 and 4.

In FIG. 3, an insulating or nonmagnetic partition 42, having a flanged or wide portion 43 in the circumferential plane of the pole tips, is employed to separate the interpolar space 29 from that of the air gap 15. The partition of is disposed in the interpolar space and suitably secured to the rim member 26.

In FIG. 4, the interpolar spaces 29 are separated from the airgap 15 by a broad band of nonmagnetic material 44 disposed about and in firm contact with the tips of the poles 27. With rotation of the rotor 14, the band 44 prevents the above-described, energy consuming air vortices from forming in the interpolar spaces. The wide portion 43 of the partition 42 performs the same function in the embodiment of FIG. 3. In addition, the partition 42 serves to reduce the area of the interpolar space to effect an increase in the velocity of airflow as accomplished in the embodiments of FIGS. 2 and 5.

By directing and separating the coolant air in the manners described above, the windage loss in a large machine can be reduced to a FIG. of one-third of that encountered in prior art machines which, in turn, results in a reduction of 25 percent of total machine losses. Such a reduction in machine losses could reduce the cost of each machine by as much as 25 percent.

Another advantage of the present invention lies in the area of low inertial machines, i.e., machines having inertia requirements low enough to permit minimum weight per kva. The power rating of the rotor 14, as herein disclosed, may be increased to match that of the water cooled stator 12, at least as far as allowed by inertia requirements, without actually requiring a water cooled rotor with its more costly and complex connecting arrangements. Thus, with the present invention the rating of the air cooled rotor 14 may approach that of a water cooled rotor (having essentially the same windage losses) while simultaneously furnishing the advantage of the more simply and economically constructed air cooling arrangement which also requires less maintenance than liquid cooled arrangements.

It should now be apparent from the foregoing description, that a new and useful gas cooling arrangement for salient pole rotors has been disclosed, the arrangement effecting a considerable reduction in windage losses in the machine in an unobvious manner.

Though the invention has been described with a certain degree of particularity, changes may be made therein without departing from the spirit and scope thereof

We claim:

1. A dynamoelectric machine having a stator member and a rotor member and a gap therebetween, said stator member having windings thereon and means for directly cooling said windings to remove at least a major portion of the heat generated therein, said rotor member including salient poles, and means for causing cooling gas to flow through the machine axially of the rotor member from one end thereof to the other, said means for directly cooling said windings being in addition to said means for causing coolant gas to flow; said rotor member having means for separating the spaces between the poles from the gap between the stator and rotor members, said means for separating comprising bridging members disposed on the rotor member in the spaces between adjacent poles, said bridging members each having a radially extending portion that partitions the space between adjacent poles and a flanged portion closing the space at the pole extremities and conforming to an arcuate surface defined by extremities of said salient poles.

2. A dynamoelectric machine having a stator member and a rotor member, said stator member having windings thereon and means for directly cooling said windings to remove at least a major portion of the heat generated therein, said rotor member including salient poles, blower means for causing air to flow axially through the machine from one end to the other, said means for directly cooling said windings being separate from said blower means; a plurality of stationary vanes

disposed adjacent the end of the machine from which the air is discharged for converting the rotational energy of the air to pressure; and bridging members mounted on the rotor member being between each pair of adjacent poles, said bridging members extending radially to the ends of the poles and having portions extending between the poles to substantially close the interpolar spaces.

3. A dynamoelectric machine having a stator member and a rotor member and a gap therebetween, said stator member having windings thereon and means for directly cooling said windings to remove at least a major portion of the heat generated therein, said rotor member including salient poles, and means for causing coolant gas to flow through the machine axially of the rotor member from one end thereof to the other, said means for directly cooling said windings being in addition to said means for causing coolant gas to flow; said poles on the rotor including field coils wound therearound, and further comprising means for restricting the area of the gas flow between poles including coil bracing structures secured to the rotor and disposed against the field windings in the space between adjacent poles while leaving an area for gas flow therethrough, the bracing structures on adjacent poles being alternately spaced in an axial direction to provide the area of gas flow with adequate gas turbulence for cooling the poles and windings.