

" LIQUID COOLED HIGH SPEED SYNCHRONOUS MACHINES "

Technical Field

5 This invention relates to liquid cooled high speed synchronous machines, and more particularly, to rotary electric machines such as brushless generators.

Background Art

Prior art of possible relevance includes the following United States Letters Patents: 3,609,420
10 issued Sept. 28, 1971 to Inagaki et al; 3,629,627 and 3,629,634 both issued December 21, 1971 to Dafler et al; 3,727,085 issued April 10, 1973 to Goetz et al; and 4,139,789 issued Feb. 13, 1979 to Hunt.

15 High speed, high power rotary electric machines have long employed liquid cooling of electrical components to increase efficiency. Various methods have been employed and generally fall into two categories. One category is that of a confined cooling system while the other category is that of a non-confined cooling system.

20 Confined cooling systems typically employ fins, ducts, tubes and the likes for conducting the coolant through the apparatus. This approach, while providing cooling, has the disadvantage of not permitting direct contact between the coolant and the sources of heat with
25 the consequence of less efficient heat transfer than might be desired. Furthermore, the structure employed necessarily results in a complex mechanical arrangement.

Non-confined cooling systems have enhanced heat transfer in that they permit direct contact of the
30 cooling medium with the source of heat. However, they

have typically suffered the disadvantage of a high drag loss resulting from the cooling medium entering the air gap between moving parts of the machine. Additionally, there may be insulation deterioration on windings as a result of the impingement of cooling oil at high velocity on such windings.

The present invention is intended to overcome the difficulties heretofore found in non-confined cooling systems of the sort mentioned above.

Summary of the invention

The invention provides a rotary electric machine, comprising in combination:

a housing;

a stator within the housing and including an armature provided with windings and a rotor-receiving opening;

a rotor journaled within the housing and located within the opening and peripherally spaced from the armature by a first air gap, the rotor carrying windings and having an interior cavity;

a stationary element affixed to the housing and extending axially into the cavity;

rotor winding energizing means including at least one winding and associated armature carried by the rotor within the cavity and radially outwardly of the stationary element and cooperating magnet means mounted on the stationary element within the cavity for generating electrical current for the rotor windings, the rotor winding energizing armature and the magnet means being separated by a second air gap;

and a coolant supply system through the rotary electric machine, comprising

first coolant passages in heat exchange relation to the stator windings;

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second coolant passages in heat exchange relation to the rotor windings;

5 barrier means in the first air gap adjacent the stator for providing fluid flow isolation between the stator and the first air gap;

means for supplying a liquid coolant to the stator through the first coolant passages;

10 means for supplying the liquid coolant from the first coolant passages to a transfer tube between the stationary element and the rotor and from the transfer tube both to the second coolant passages and through radially directed openings in the transfer tube to the rotor winding energizing means; and

15 means for preventing coolant from entering the second air gap during operation of the machine.

In one embodiment of the invention, the means for preventing coolant from entering the second air gap comprises at least one coolant vent leading from the rotor cavity, located radially inwardly of the cavity periphery and radially outwardly of the second air gap.

20 Preferably the means for supplying liquid coolant to the stator comprises an inlet to the housing adjacent one side of the stator and separated from the first air gap by the barrier means; and a conduit in the housing leads from the side of the stator through a conduit in the stationary element to the transfer tube and thence to the second coolant passages and to the rotor cavity.

25 Advantageously there is a conduit through the stationary element and the transfer tube rotatable with the rotor which interconnects the rotor and the conduit. The radially directed openings in the transfer tube preferably comprise spray means for directing coolant at the rotor winding energizing means and associated armature.

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Typically, the rotor is journalled in the housing by bearings at opposite ends of the rotor. In a preferred embodiment, one of the conduits includes at least one opening adjacent the bearings so that a
5 portion of the coolant in the conduit may exit the same to lubricate the bearings.

Brief Description of the Drawings

Fig. 1 is a sectional view of a rotary electric machine, specifically a brushless generator, made according to the invention;

5 Fig. 2 is an enlarged fragmentary sectional view illustrating one means of providing coolant to stator windings;

10 Fig. 3 is an enlarged fragmentary view illustrating one means of providing lubricant to windings carried by the rotor;

Fig. 4 is a view similar to Fig. 3 showing an alternative means of providing coolant to rotor windings; and

15 Fig. 5 is an enlarged view illustrating a means whereby coolant may be employed to lubricate bearings and yet be prevented from entering an air gap.

Best Mode For Carrying Out The Invention

20 An exemplary embodiment of a rotary electric machine made according to the invention in the form of a brushless generator is illustrated in the drawings and with reference to Fig. 1 is seen to include a housing, generally designated 10. The housing 10, at one end, includes an end cap 12 provided with a central opening 14
25 in which bearings 16 are disposed.

At the opposite end of the housing 10, the same includes an internal recess 18 for receipt of bearings 20. A rotor, generally designated 22, has its opposite ends journaled in the bearings 16 and 20 within the
30 housing 10.

Within the housing 10 is a stator, generally designated 24 including an armature 26 provided with windings 28 having end turns 30 extending from opposite

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sides of the armature 26. The armature 26 also includes a central opening 32 through which the rotor 22 extends but is spaced therefrom by a small peripheral air gap 34.

5 Within the housing 10 oppositely of the end cap 12 is a radially inwardly directed web 36 having its radially inner end 38 provided with radially inwardly opening grooves 40. O-ring seals 42 are disposed within the grooves 40.

10 The end cap 12 includes radially outwardly opening grooves 44 receiving similar O-rings 46. A cylindrical, liquid impervious barrier 48 is fitted within the opening 32 in the armature 26 so as to abut the latter and thereby be spaced from the periphery of the rotor 22. The barrier 48 has sufficient axial length so as to have
15 its opposite ends sealingly engaged by the seals 42 and the seals 46. As will be seen, the barrier 48 serves to isolate the air gap 34 from liquid coolant. In order to avoid disruption of the magnetic field of the machine, the barrier 48 is made of non-magnetic material.

20 The rotor 22 includes a generally cylindrical can 50 defining its outer periphery. At one end, the can 50 has a reduced diameter section 52 journaled in the bearings 20. An opposite reduced diameter section 54 is journaled in the bearing 16 and is adapted to be driven
25 by any suitable source of motive power (not shown).

 Within the can 50, the rotor 22 includes main rotor magnetics in the area shown at 56 aligned with the armature 26 of the stator 24. To one side thereof, the rotor 50 includes an interior cavity 58.

30 Coaxial with the axis of rotation of the rotor 22 and within the housing 10 is a stationary element 60 which extends into the cavity 58. The element 60 has a hollow interior 62 defining a conduit. The element 60

may be secured to the interior of the housing 10 by any suitable means and the housing 10 itself includes a conduit 64 opening as at 66 on one end to the left-hand side of the stator 24 as viewed in Fig. 1. At its opposite end, the conduit 64 opens as at 70 to the conduit 62 in the stationary element 60.

On the side of the stator 24 opposite from the opening 66, the housing 10 is provided with an inlet 72 through which coolant which preferably is a combination lubricant and coolant may be introduced. The coolant follows the path indicated by an arrow 74 through passages to be described in the armature 26 to enter the conduit 64 and ultimately be directed to the interior of the stationary element 60. This coolant is prevented from entering the air gap 34 by the barrier 48.

The conduit 64 includes a branch or opening 76 within the housing 10 extending to the bearings 20. Consequently, certain of the coolant introduced into the housing 10 via the inlet 72 may be supplied to the bearings 20 for lubricating purposes after it has cooled the stator 24.

A transfer tube 78, which may be of conventional construction, has one end 80 disposed within the conduit 62 in the stationary element 60 and its opposite end 82 in fluid communication with passages to be described in the main rotor magnetics 56. The transfer tube 78 is preferably, though not necessarily, rotatable with the rotor and is operable to conduct coolant in the conduit 62 to the previously alluded to passages for cooling of the main portion of the rotor.

Within the cavity 58, there is located a permanent magnet generator, generally designated 90 and an exciter, generally designated 92. The permanent magnet generator

90 includes a series of permanent magnets 94 mounted on the interior of the can 50 and thus forming the rotor of the permanent magnet generator 90. A stator 96 having windings 98 for the permanent magnet generator 90 is
5 located in the cavity 58 in axial alignment with the permanent magnets 94 and is secured to the stationary element 60 by any suitable means. The stator 96 is separated from the magnets 94 by a small air gap 100.

The exciter 92 includes a stator 102 having windings
10 104 secured to the stationary element 60 within the cavity 58. Additionally, the exciter 92 includes a rotor 106 radially outwardly of the stator 102 and carried by the interior of the rotor can 50. The rotor 106 of the exciter 92 likewise has windings as are shown at 108.
15 The exciter stator 102 and exciter rotor 106 are radially separated by a small air gap 110.

As is well known, the permanent magnet generator 90 provides sufficient induced current to create a magnetic field in the exciter 92. This in turn causes generation
20 of current in the exciter rotor windings 108, usually as alternating current, which is then rectified by means not shown to energize the main rotor windings which in turn causes the induction of current within the stator windings 30 which is employed as is desired.

25 The transfer tube 78 includes generally radially directed bores 112 which serves as spray means or nozzles allowing coolant to exit generally radially within the rotor 22. It will be observed that the bores 112 are axially spaced from the air gaps 100 and 110 and aligned
30 with portions of the windings 104 and 108. Consequently, the radially flowing coolant impinges upon such windings to provide cooling action. During rotation of the rotor 22, centrifugal force will cause the coolant to closely

conform to the interior of the cavity 58 once it has exited the bores 112 and thus, the same will come in contact with the permanent magnet generator rotor 94 and the exciter rotor 106.

5 At the left-hand side, the rotor 22 includes one or more vents 114 which are located radially outwardly of the air gaps 100 and 110 but radially inwardly of the periphery 116 of the cavity 58. Consequently, during operation of the device, there will be a hollow
10 cylindrical body of coolant within the cavity 58 closely conforming to the periphery 116 of the cavity 58. As additional coolant emanates from the bores 112, the radially inner surface of such body of coolant will move radially inwardly until such time as it reaches the
15 location of the vent or vents 114. The same may then exit the interior cavity 58 of the rotor 22 and flow into a collection space 116 within the housing 10. From the collection space 116, the coolant may be recirculated back to the inlet 72 by any suitable and conventional
20 means.

As can be seen, the location of the vent 114 thus assures the presence of a sufficient body of coolant to provide cooling action for the permanent magnetic generator 90 and the exciter 92 and yet prevents, during
25 operation of the machine, the entry of such coolant into the air gaps 100 and 110.

Coolant exiting the end 82 of the transfer tube 78 flows through passages in the main portion 58 of the rotor 22 as generally alluded previously as illustrated
30 by arrows 120. At the reduced diameter section 54, the streams of coolant converge and exit the rotor via the hollow center 122 of the reduced diameter section 54. Prior to that occurring, some of the coolant will enter

radially directed bores 124 in the reduced diameter section 54 which are closely adjacent the bearings 16. The coolant emanating from such bores 124 is caused to lubricate the bearings 16 by the presence of an annular baffle 126 having a radially inwardly directed flange 128 axially spaced to one side of the bores 124 sufficiently so as to intercept all oil or coolant emanating therefrom before the same can travel radially outwardly to the air gap 32 as best seen in Fig. 5.

Turning now to Fig. 2, one means of providing oil or coolant flow paths through the armature 26 is illustrated. As is well known, the armature 26 is provided with slots 130 receiving stator windings 132. Suitable insulation 134 surrounds the windings 132 and the lowermost winding 132 is spaced from the bottom of the slot 130 so as to define a channel 136 through which coolant may travel. The channels 136 open from the armature 26 at its opposite ends.

Coolant may also flow through the open upper ends 138 of the slots 130. Thus, direct contact of the coolant with the windings is assured to enhance cooling capacity.

In the case of the rotor, two methods of providing passages therethrough are illustrated in Figs. 3 and 4. In the case of the machine shown, the rotor is a two pole type and is provided with a series of laminations 140 having radially openings slots 142 spaced from each other by 180°. As shown in Fig. 3, the windings of the rotor may be formed of rectangular copper 144 as is well known. The rectangular copper pieces 144 are spaced from each other by gaps 146 which serve as cooling channels for the passage of the coolant axially along the length of the rotor.

Alternatively, and as shown in Fig. 4, where the windings are formed of circular cross section conductors 148, typically of copper, it will be appreciated that the naturally occurring voids such as seen at 150 between the conductors form longitudinal coolant passages for the flow of the coolant. Again, direct contact of the coolant with the conductors is provided to maximize cooling efficiency.

From the foregoing, it will be appreciated that a rotary electric machine made according to the invention avoids inefficiencies due to drag loss resulting from the entry of coolant into air gaps by the use of the barrier 48 and the unique location of the vent 114. At the same time, it will be appreciated that maximum heat transfer is provided by reason of direct contact between the coolant and windings. High velocity liquid impingement on components is virtually totally avoided to minimize insulation deterioration resulting from that action. Consequently, the advantages of a non-confined cooling system over confined cooling systems are retained while the disadvantages are avoided.



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CLAIMS

1. A rotary electric machine, comprising in combination:
 - a housing;
 - a stator within the housing and including an armature provided with windings and a rotor-receiving opening;
 - a rotor journaled within the housing and located within the opening and peripherally spaced from the armature by a first air gap, the rotor carrying windings and having an interior cavity;
 - a stationary element affixed to the housing and extending axially into the cavity;
 - rotor winding energizing means including at least one winding and associated armature carried by the rotor within the cavity and radially outwardly of the stationary element and cooperating magnet means mounted on the stationary element within the cavity for generating electrical current for the rotor windings, the rotor winding energizing armature and the magnet means being separated by a second air gap;
 - and a coolant supply system through the rotary electric machine, comprising
 - first coolant passages in heat exchange relation to the stator windings;
 - second coolant passages in heat exchange relation to the rotor windings;
 - barrier means in the first air gap adjacent the stator for providing fluid flow isolation between the stator and the first air gap;
 - means for supplying a liquid coolant to the stator through the first coolant passages;
 - means for supplying the liquid coolant from the first coolant passages to a transfer tube between the



stationary element and the rotor and from the transfer tube both to the second coolant passages and through radially directed openings in the transfer tube to the rotor winding energizing means; and

5 means for preventing coolant from entering the second air gap during operation of the machine.

10 2. A rotary electric machine according to claim 1, wherein the means for preventing coolant from entering the second air gap comprises at least one coolant vent leading from the rotor cavity, located radially inwardly of the cavity periphery and radially outwardly of the second air gap.

15 3. A rotary electric machine according to any preceding claim, wherein the means for supplying liquid coolant to the stator comprises an inlet to the housing adjacent one side of the stator and separated from the first air gap by the barrier means; and a conduit in
20 the housing leads from the other side of the stator through a conduit in the stationary element to the transfer tube.

25 4. A rotary electric machine according to any preceding claim, wherein the radially directed openings in the transfer tube comprise spray means for directing coolant at the rotor winding energizing means.

30 5. A rotary electric machine according to claim 4, wherein the spray means direct coolant generally radially at a location axially spaced from the second air gap.



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- 5 6. A rotary electric machine according to any preceding claim, wherein the rotor is journaled in the housing by bearings at opposite ends of the rotor and the means for supplying the coolant from the first coolant passages to the transfer tube includes at least one opening adjacent each of the bearings whereby a portion of the coolant is utilized to lubricate the bearings.
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