

(12) **UK Patent Application** (19) **GB** (11) **2 425 662** (13) **A**

(43) Date of A Publication **01.11.2006**

(21) Application No: **0508330.8**
(22) Date of Filing: **25.04.2005**

(51) INT CL:
H02K 3/24 (2006.01) **H02K 1/24** (2006.01)
H02K 1/32 (2006.01) **H02K 9/00** (2006.01)

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(52) UK CL (Edition X):
H2A ARC4 ARC7 ARD4 AR117 AR120 AR121 AR214R
AR215R AR216R AR220R AR302R AR303R AR601R
AR607R AR610 AR611

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(58) Field of Search:
UK CL (Edition X) **H2A**
INT CL **H02K**
Other:

(54) Abstract Title: **Rotor cooling**

(57) At least one of the salient poles comprises a main pole body on which is wound at least two layers of windings, and a pole shoe arranged at least partial to overlap the windings in a circumferential direction so as to retain the windings, a cooling duct (32, 34) being provided between two layers of windings in an area which is overlapped by the pole shoe. Spacers 40 create the duct and may extend beyond the winding to enhance heat exchange. Coolant is supplied via channel 30 formed by bridge parts 38 formed on laminations and exit grooves may be present on the underside of the pole shoes, which structures may be provided by stacking adjacent identical lamination rotated though one pole position. The separators may be of insulation material or metal insulated where it is within the windings.

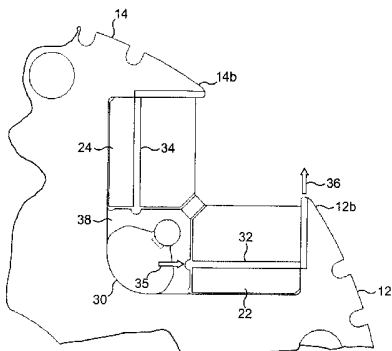


FIG. 2

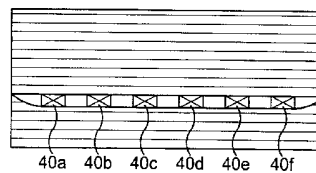


FIG. 3

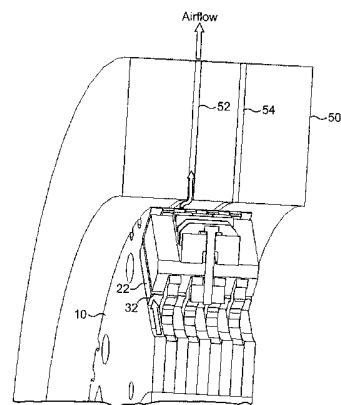


FIG. 7

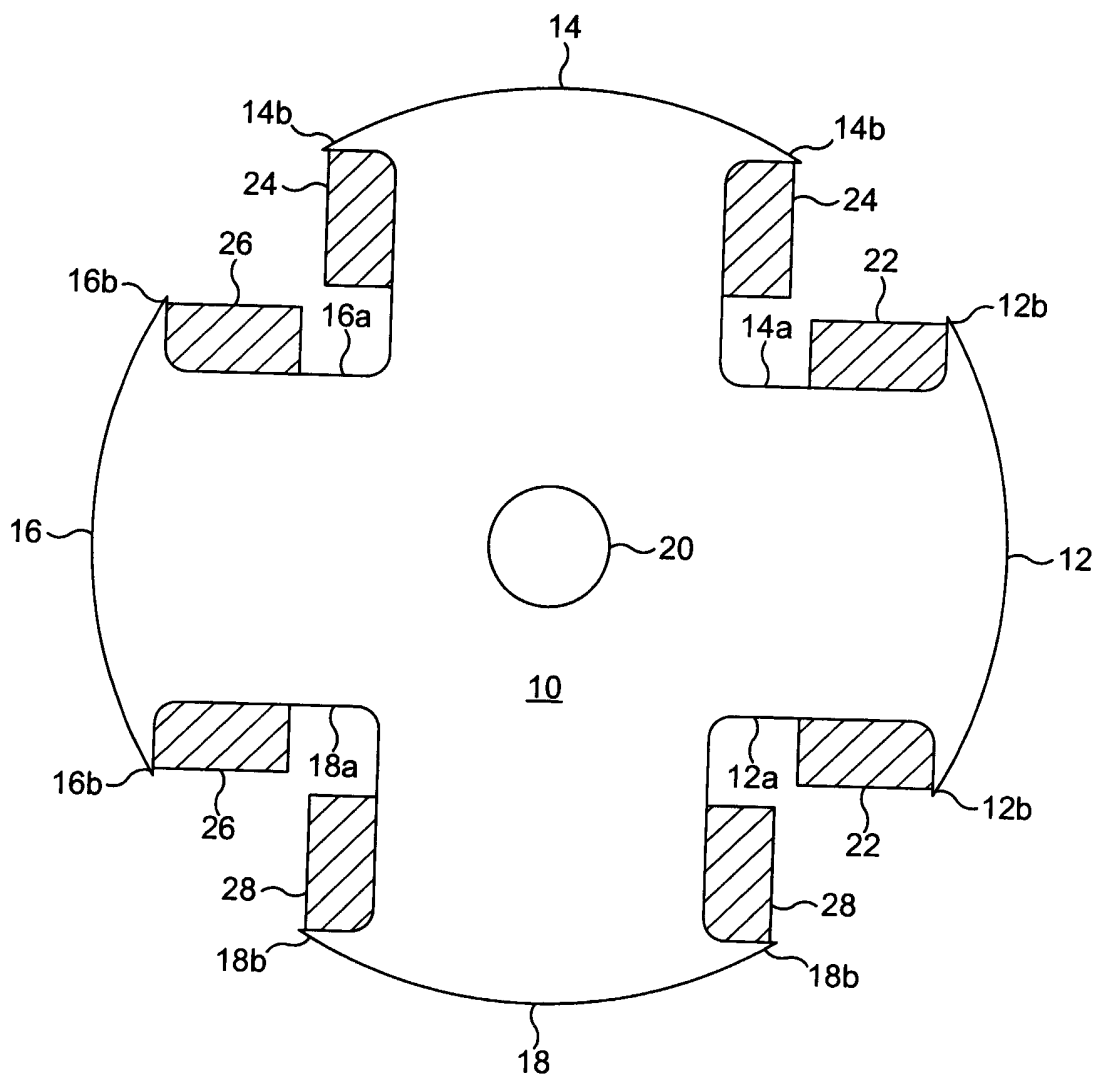


FIG. 1

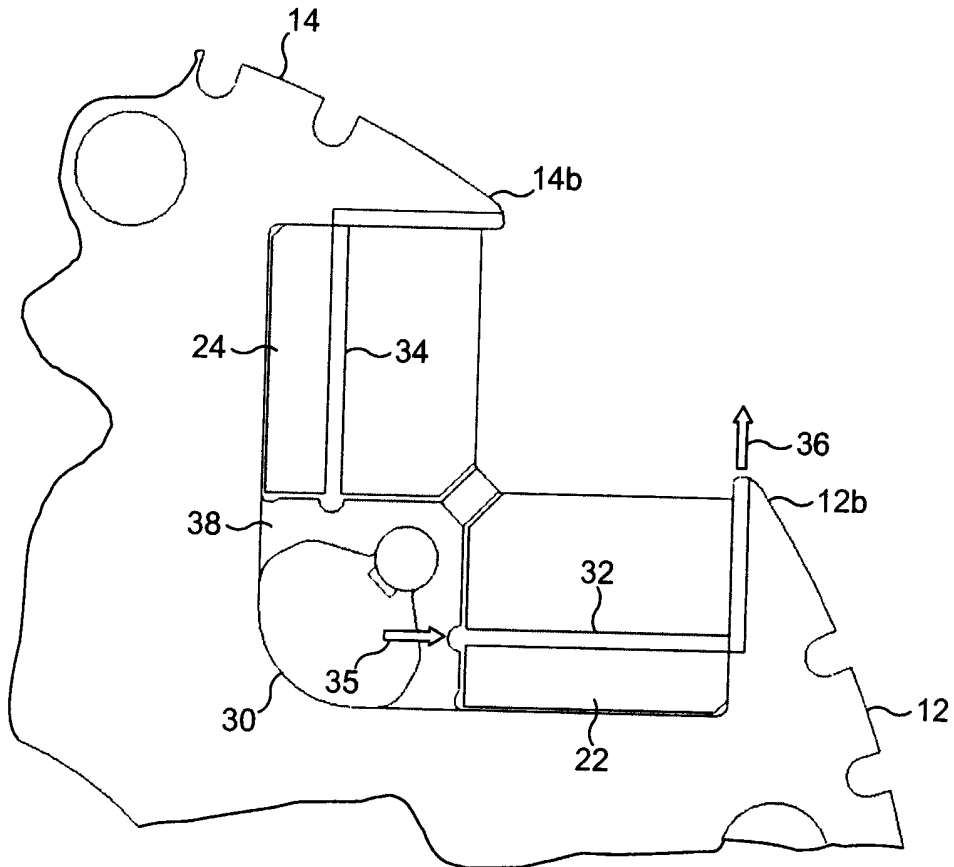


FIG. 2

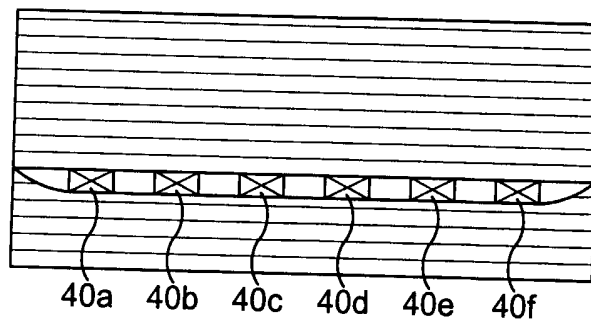


FIG. 3

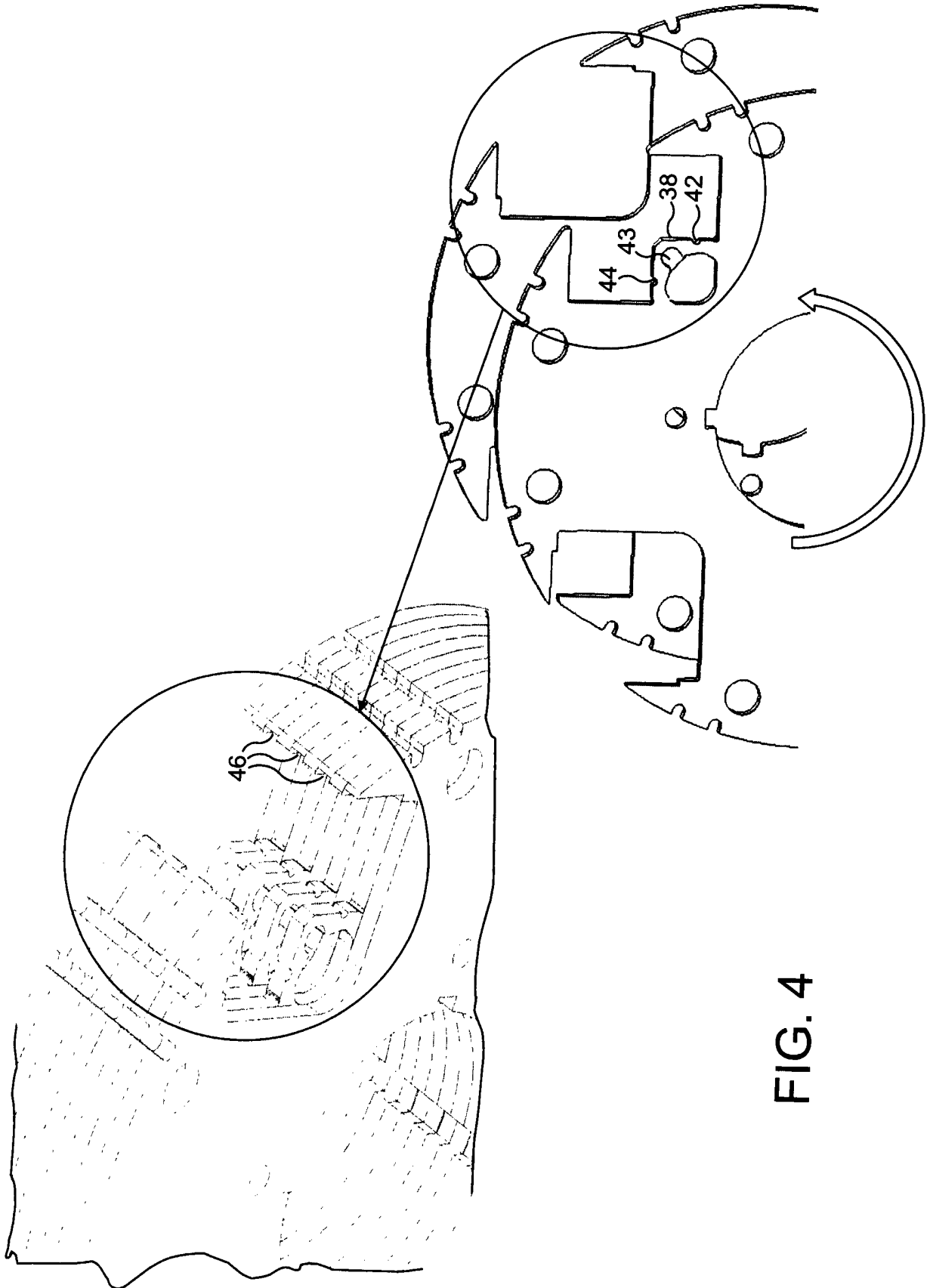


FIG. 4

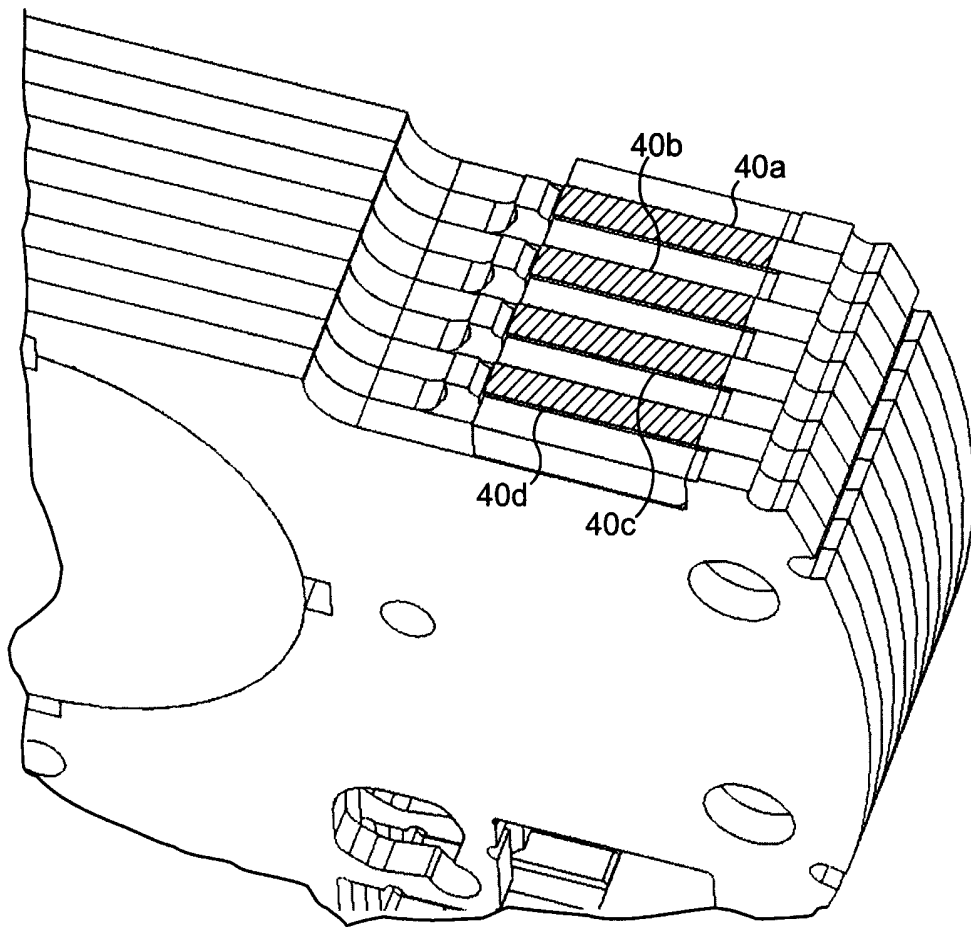


FIG. 5

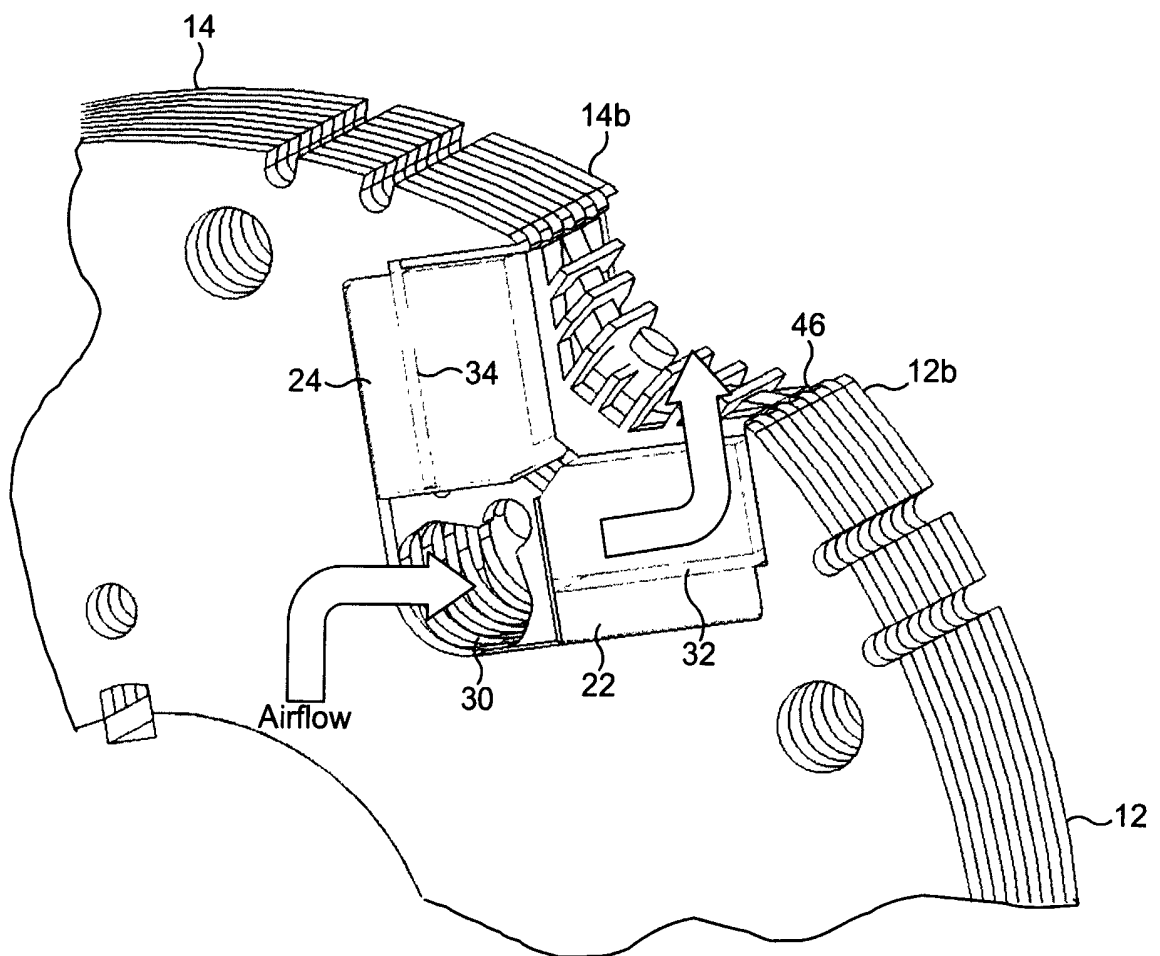


FIG. 6

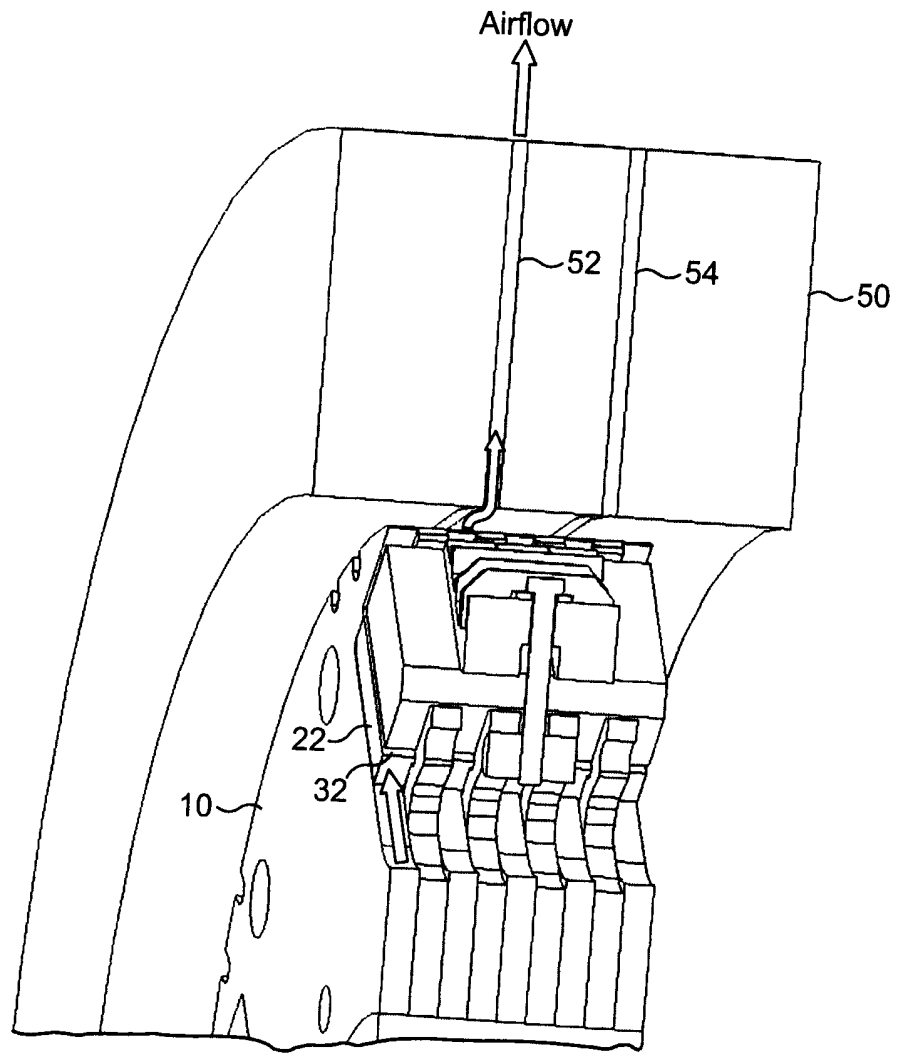


FIG. 7

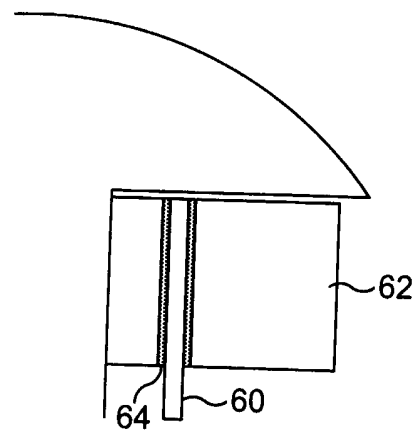


FIG. 8

ROTOR COOLING

The present invention relates to rotating electrical machines of a salient pole design,
5 and in particular to techniques for improving the cooling of such machines.

Rotating electrical machines, such as motors and generators, generally comprise a rotor and a stator, which are arranged such that a magnetic flux is developed between the two. In a rotating machine of a salient pole design, the rotor has a plurality of
10 poles which extend radially outwards, on which a conductor is wound. An electrical current flowing in these windings causes a magnetic flux to flow across the air gap between the rotor and the stator. In the case of a generator, when the rotor is rotated by a prime mover, the rotating magnetic field causes an electrical current to flow in the stator windings, thereby generating the output power. In the case of a motor, an
15 electrical current is supplied to the stator windings and the thus generated magnetic field causes the rotor to rotate.

In a salient pole machine, as the rotor rotates centrifugal forces develop on the windings, which tends to force the windings outwards in a radial direction. For this
20 reason many salient pole machines have pole shoes at the pole tip, and these shoes overlap the rotor windings. The pole shoes thus assist in retaining the windings against the centrifugal forces developed as the rotor rotates.

In electrical machines losses may occur due to, for example, resistance in the
25 windings and in losses in the pole body. These losses result in heat being created within the machine. The machine rating is determined by the actual temperature rise of the rotor and stator, and thus the cooling efficiency of the construction may help to determine the rating of the machine.

30 Known techniques for cooling the rotor include creating air gaps in the rotor windings outhangs, and providing the rotor with finned wedging devices. However there remains a need to provide more efficient cooling of the rotor.

According to a first aspect of the present invention there is provided a rotor for a rotating electrical machine, the rotor comprising a plurality of salient poles, at least one of the poles comprising a main pole body on which is wound at least two layers of windings, and a pole shoe arranged at least partially to overlap the windings in a circumferential direction so as to retain the windings, wherein a cooling duct is provided between two layers of windings in an area which is overlapped by the pole shoe.

The present invention is based on the realisation that the hottest part of the rotor windings is likely to be the part which lies underneath the pole shoes. Thus, by providing a cooling duct between two layers of windings in an area which is overlapped by the pole shoe, the windings can be cooled at their hottest point. This may increase the efficiency of the rotor cooling, which in turn may improve the machine's efficiency due to lower resistive losses in the windings, or may increase the machine's power rating. Furthermore, the maximum temperature seen in the rotor winding may be reduced, which may extend its life expectancy.

The cooling duct may be formed by providing a strip of material between the two layers of windings. For example, a strip of substantially rectangular cross section may be used, in which case ducts may be created on either side of the strip. However strips of other cross section may be used, and the cross section may be tailored to conform to the shape of duct it is required to create. For example, to create a duct of substantially rectangular cross section, two strips of substantially triangular in profile section may be used, which are spaced apart to create the duct.

The strip may be made from an electrical insulator, such as glass epoxy or other material, in order to reduce the risk of a short circuit in the windings. The strip may be a heat insulator, and preferably can withstand high temperatures.

Alternatively the strip may be from a thermally conductive material, and part of the strip may extend out of the windings, for example in a radially inward direction. In this way cooling of the windings can also take place through thermal conduction through the strip. Preferably the part of the strip which extends out of the windings is in the air flow caused by the rotation of the rotor, for example the air flow through an

axial channel under the windings. The thermally conductive material may be metal, such as copper or aluminium, or some other material. Where the strip is made of metal, a part of the strip inside the windings may be insulated, and a part of the strip outside the windings may be uninsulated for best heat transfer. This may reduce the risk of a short circuit in the windings, while providing effective cooling.

Preferably the strip extends in a substantially radial direction, that is to say, one end of the strip is closer to the centre of rotation than the other. A strip may be an individual piece, or it may be part of a matrix of strips.

Preferably, for optimum cooling, the strip is positioned towards the middle of the windings, for example, at a location between 25% and 75% across the windings in a circumferential direction. However, since the inside of the windings (i.e. the part closest to the pole) may become hotter than the outside, the position of the duct may be offset towards the inside of the windings. Thus the strip may be located at a location between 50% and 75% across the windings in a circumferential direction. Generally, the position of the duct will be at or close to the point where the temperature would otherwise be the highest.

A single duct may be provided, or, in order to increase the cooling, a plurality of ducts may be provided between the layers of windings. For example, a plurality of ducts may be provided between the same two layers of windings, and/or a plurality of ducts may be provided between different layers of windings.

Preferably the duct has an entry path and an exit path, to allow the passage of a cooling fluid (such as air) through the duct. Preferably the entry path is located at a point closer to the axis of rotation than the exit path. By providing the entry path closer to the axis of rotation than the exit path, centrifugal force due to rotation of the rotor may cause the cooling fluid to flow through the duct. This can avoid the need for a separate mechanism, such as a fan, to propel the cooling fluid.

The entry path may be located on a bottom surface, in a radial direction, of the windings. In this case the rotor may have an axial channel under the bottom surface of

the windings, which channel is in communication with the duct. This channel can then supply the cooling fluid to the duct.

5 In order to hold the windings in place, the rotor may be provided with a bridging member which bridges two adjacent poles and abuts the bottom of the windings. The channel may then be formed in an axial direction through such a bridging member.

The bridging member may have an additional channel for accommodating a retaining piece for engagement with a connecting member for connecting a wedge to the rotor.
10 This additional channel may be closed, or may open partially into the cooling channel or towards the wedge. Such an arrangement is described in the co-pending patent application entitled "Wedging Arrangement" in the name of Newage International Limited and having the same filing date as the present application (representative's reference MIW/SS/43159), the entire contents of which are incorporated herein by
15 reference.

Rotors in electrical machines are usually formed from a plurality of laminations (e.g. laminated sheets of metal), in order to reduce eddy currents flowing in the rotor. In order to provide a path between the channel and the duct, where the rotor is formed
20 from a plurality of laminations, one or a group of laminations may have no bridging member, or only part of a bridging member, between two adjacent poles. The thus resulting gap may then provide the path between the channel and the duct.

In a rotor formed in this way, the intermittent nature of the bridging members may
25 increase the exposed surface area of the laminations, which may improve the cooling. Furthermore, the intermittent bridging members may give rise to turbulence in the flow of the cooling fluid, which may also improve the cooling.

The exit path may be located on a top surface, in a radial direction, of the windings.
30 The natural way to achieve this would be to remove some of the windings. However this would reduce the capacity of the windings, and hence the amount of flux produced by the rotor. Therefore in a preferred embodiment of the invention a groove is provided in the pole shoe, which groove provides the exit path.

In order to form the groove, where the rotor is formed from a plurality of laminations, one or a group of laminations may be recessed at a part of the pole shoe which abuts the windings, with respect to the other laminations. This recess may then form the groove between the windings and the pole shoe, which groove provides the exit path.

5

When manufacturing a rotor in accordance with the present invention, the rotor may be formed from a plurality of laminations, each of the laminations being the same shape, and one or a group of laminations may be rotated with respect to the other laminations. This technique can allow an entry and/or exit path to be provided for the duct without the need for different shapes of laminations, which may make the manufacturing process more efficient. This can be achieved by arranging the laminations to have an asymmetrical profile. For example, at least one of the poles in each lamination may have a different profile from at least one of the other poles in the same lamination. When one or a group of laminations is rotated with respect to the other laminations, the mis-matches between the poles may create an entry and/or exit path.

10
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For example, in each lamination, bridging members may be provided between some adjacent poles, but not others. When one or a group of laminations is rotated with respect to the other laminations, the missing bridging members may provide a path between the duct and a channel through the bridging members.

20

Furthermore, in each lamination, one pole shoe may be recessed at a part of the pole shoe which abuts the windings, with respect to another pole shoe in the same lamination. When one or a group of laminations is rotated with respect to the other laminations, the recess may form a groove between the windings and the pole shoe, which groove provides the exit path.

25

The lamination or group of laminations may be rotated by the angle between the poles, or a multiple thereof, with respect to the other laminations. For example, if alternate poles have different profiles, the lamination or group of laminations may be rotated by the angle between the poles (e.g. 90° in a four pole machine). If only one pole (or some other subset of the poles) has a different profile than the other poles,

30

different laminations or groups of laminations may be rotated by different multiples of the angle between the poles.

Laminations for rotors are usually made from rolled sheet steel. During manufacture
5 of the rolled steel there may be a slight crowning across the width of the roll due to
deflections in the roller. This crowning effect may lead to a rotor having slight
differences in the mass of steel in different poles. Rotating groups of laminations with
respect to other laminations may also produce the advantage that the mass of steel in
each pole can be made more uniform. This may help to reduce vibration, and may also
10 have the effect of raising the maximum flux density before saturation on the complete
rotating field, thereby raising the rating of the machine.

Preferably each pole is provided with a cooling duct. A pole may be provided with a
duct on each side, in order to ensure that both sides are cooled.

15 An exit path for a duct may lie at least partially in a circumferential direction. Where a
pole is provided with a duct on each side, one exit path may then evacuate air on a
windward side, and one exit path may evacuate air on a leeward side, when the rotor
is rotated. Such an arrangement can help to ensure that temperature differentials in the
20 rotor are kept to a minimum. This is because the windward side of a rotor will
generally be better cooled than the leeward side. However an exit path which is
located on the leeward side will evacuate air better than an exit path located on the
windward side, due to the reduced pressure at the leeward side. Therefore the cooling
fluid may flow more rapidly through the duct located on the leeward side, which may
25 increase the cooling effect produced by the duct, with respect to the duct on the
windward side. This may reduce the temperature differential which may otherwise
occur between the windward and leeward sides of the rotor. Such an arrangement may
therefore reduce the effects of differential axial thermal growth and the associated
potential for damage to the enamel or other insulation on the windings. Reducing the
30 differential thermal growth across the windings may also reduce the potential for
micromovement, and may minimise the potential for turn to turn or layer to layer DC
short circuits. Furthermore, stresses on other components, such as wedges or retaining
bolts, due to thermal growth may be reduced.

The windings may be of any suitable type, such as copper wires, and may be of any cross section, such as round or rectangular. The rotor poles may be formed from any suitable magnetic material such as iron or steel. The cooling fluid may be air or another gas, or a liquid coolant.

5

The invention extends to a rotating electrical machine, such as a generator or motor, comprising a stator, and a rotor in any of the forms described above.

The invention also provides a method of manufacturing a rotor for a rotating electrical machine, the rotor comprising a plurality of salient poles, at least one of the poles comprising a main pole body and a pole shoe, the method comprising winding a first layer of windings on the pole main body, positioning a strip of material on the first layer of windings, and winding a second layer of windings on top of the first layer and the strip such that a cooling duct is formed between the two layers of windings in an area which is overlapped by the pole shoe.

15

As mentioned above, rotating some laminations with respect to others may produce the advantage that the mass of steel in each pole can be made more uniform.

20 According to another aspect of the invention there is provided a method of manufacturing a rotor for a rotating electrical machine, the rotor comprising a plurality of salient poles, the method comprising:

forming a plurality of laminations each having the same profile; and
rotating one or a group of laminations by the angle between the poles, or a
25 multiple thereof, with respect to the other laminations, to form a rotor body.

25

Each lamination may have an asymmetrical profile. For example, each lamination may have at least one pole with a different profile from at least one of the other poles. In each lamination, bridging members may be provided between some adjacent poles, but not others. Alternatively or in addition one pole shoe may be recessed at a part of
30 the pole shoe which abuts the windings, with respect to another pole shoe in the same lamination. Such methods can allow a rotor to be manufactured with holes or grooves for a cooling fluid, without the need to produce laminations with different profiles.

30

According to another aspect of the invention there is provided a rotor for a rotating electrical machine, the rotor comprising a plurality of salient poles, wherein the rotor has a rotor body which is formed from a plurality of laminations each having the same profile, in which one or a group of laminations has been rotated by the angle between the poles, or a multiple thereof.

Features of one aspect of the invention may be applied to another other aspect. Any of the apparatus features may be provided as method features and *vice versa*.

Preferred features of the present invention will now be described, purely by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a cross section of a rotor;

Figure 2 shows part of a rotor in accordance with an embodiment of the present invention;

Figure 3 shows a cross section through part of a winding;

Figure 4 shows parts of a rotor body;

Figure 5 shows a cut away part of a rotor pole;

Figure 6 shows parts of a rotor with the windings in place;

Figure 7 shows parts of a rotor and a stator in a rotating electrical machine in accordance with an embodiment of the invention; and

Figure 8 shows an alternative arrangement of a strip of material for forming a cooling duct.

Figure 1 shows a cross section of a rotor to which the present invention may be applied. Referring to Figure 1, a rotor body 10 is formed from a plurality of laminated sheets of metal to create a rotor of the required thickness. The rotor body 10 comprises a plurality of salient poles 12, 14, 16, 18 each of which comprises a pole main body 12a, 14a, 16a, 18a, and a pole shoe 12b, 14b, 16b, 18b. Each pole main body is wound with a respective winding 22, 24, 26, 28.

In operation, the rotor rotates about central axis 20. An electrical current is supplied to the windings 22, 24, 26, 28, which causes a magnetic flux to develop between the rotor and the stator (not shown). The pole shoes 12b, 14b, 16b, 18b are arranged to

assist in retaining the windings 22, 24, 26, 28 against centrifugal force as the rotor rotates.

Figure 2 shows part of a rotor in accordance with an embodiment of the present invention. In Figure 2, rotor pole 12 carries windings 22, and rotor pole 14 carries
5 windings 24. A bridging member 38 is provided to hold the windings in place.

As can be seen from Figure 2, the windings 22 are provided with a cooling duct 32. This cooling duct extends through the windings in a radial direction. A similar duct
10 34 is provided through windings 24. A channel 30 is provided in an axial direction through the bridging member 38. The channel 30 is in communication with each of the ducts 32, 34, so as to allow air to flow from the channel 30 into the ducts. Each of the ducts 32, 34 is provided with an exit path which extends across the top of the windings under the pole shoe 12b, 14b in a circumferential direction.

15 In operation, as the rotor rotates, air is propelled through the ducts 32, 34 by centrifugal force as indicated by arrows 35, 36. The air flow through the ducts 32, 34 acts to cool the windings 22, 24. The ducts 32, 34 are located at that part of the windings 22, 24 which would otherwise experience the highest temperature rise, in
20 order to provide the most effective cooling of the windings.

As indicated in Figure 2, a duct is provided on each side of a rotor pole, in order to ensure that both sides of the pole are cooled. In this embodiment a plurality of ducts are provided through the windings in an axial direction (coming out of the plane of the
25 paper in Figure 2). Further ducts may also be provided through the windings in a circumferential direction.

Figure 3 shows a cross section through one of the windings 22, looking outwards in a radial direction. In Figure 3 the windings run from left to right. Within the windings
30 22 are located strips of material 40a to 40f made of glass epoxy, or similar material. The presence of the strips of material between the windings causes air gaps to form on either side of the strips. These air gaps form ducts 32 through which the cooling air can flow.

Figure 4 shows how the rotor body is formed so as to allow air to enter and exit the cooling ducts. As can be seen in Figure 4, the rotor body is formed from a plurality of laminated sheets of metal which are placed together. In each lamination, alternate pairs of poles are provided with a bridging member 38, while between the other pairs of poles this bridging member is missing. A group of laminations is then rotated through 90° with respect to an adjacent group of laminations so that, at any one pole, there will be alternating groups of laminations with and without a bridging member 38. Each bridging member 38 has a cut out centre, and these cut-outs form the channel 30 through which air can flow. Each bridging member 38 is provided with two notches 42, 44 which are located at the positions in which it is desired to provide the strips of material 40a-40f.

When the rotor is wound, a first layer of windings is first wound up to the level of the notches 42, 44. Strips of material 40a-40f are then laid across the first layer of windings between the notches and the pole shoes. If desired, corresponding notches could also be provided in the pole shoes. The strips of material are aligned with the groups of laminations having the bridging members 38.

Figure 5 shows a cut away part of a rotor pole, with the strips of material 40a-40f located on top of the first layer of windings.

A second layer of windings is then added on top of the first windings and the strips of material. The presence of the strips of material causes ducts to be formed between the windings as shown in Figure 3. Since the strips of material are aligned with the bridging members 38, the ducts 32, 34 are formed on each side of the bridging members 38, with openings at locations where there are no bridging members. In this way the ducts open into the channel 30 which is formed through the bridging members 38.

Referring back to Figure 4, the pole shoes which are on a side of a pole body with no bridging member are slightly cut away with respect to pole shoes which are above a bridging member. The effect of this is to produce a plurality of grooves 46 in the pole shoes, which grooves are in-line with the gaps between the bridging members 38. When the rotor is wound, the strips of material 40a – 40f lie between the bridging

members 38 and the non cut-away parts of the pole shoes. The air ducts formed on either side of the strips of material thus open into the grooves 46 formed by the cut away pole shoes. The grooves 46 thus form exit paths for the cooling air flowing through the ducts 32, 34.

5

Providing an exit path in the form of grooves 46 in the way shown in Figure 4 avoids the need to remove any of the windings in order to evacuate the air from the ducts. This arrangement therefore does not significantly reduce the flux produced by the rotor, since there is no reduction in the number of turns. Since alternate groups of laminations do not have cut-away pole shoes, the pole shoes can retain their physical strength, and also their ability to develop the required magnetic flux.

10

The arrangement described above can allow each lamination to be the same, and the rotor to be formed simply by rotating groups of laminations through 90° as an example. This can reduce the manufacturing costs compared to the case where different types of laminations are used. Furthermore, rotating groups of laminations with respect to other laminations may also compensate for crowning effects in the steel, and thus may help to ensure that the mass of steel in each pole is uniform

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In an alternative arrangement, different laminations or groups of laminations are indexed by different amounts. For example, in a four pole machine, different groups of laminations may be rotated by 90° , 180° , and 270° respectively. Such an arrangement can allow a different number of bridging members and pole shoe recesses to be provided in the laminations. For example, a single bridging member could be provided per lamination. The effect of this would be to reduce the number of bridging members in any one axial channel, which may improve air flow to the ducts and allow part of a strip of material to extend below the windings. In general any number and combination of bridging members and poles shoes recesses may be provided in the laminations.

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Referring again to Figure 4, it can be seen that the bridging members 40 are provided with a semi-closed slot 43 which extends in an axial direction through the bridging members. This slot 43 can be used to accommodate a tapped bar, into which a bolt

can be screwed for securing a wedge. This arrangement is described in the co-pending patent application entitled "Wedging Arrangement" referred to above.

Figure 6 shows in more detail parts of the rotor with the windings in place. As indicated in Figure 6, when the rotor is rotated, centrifugal force propels air through the channel 30, the ducts 32, 34 and out through the grooves 46 in the pole shoes 12b, 14b. The effect of this air flow is to cool the rotor windings in the area around the ducts.

10 It can be seen from Figures 2 and 6 that air will exit on one side of a rotor pole in the windward direction, and on the other side of the rotor pole in a leeward direction. In general, the windward side of a rotor pole is better cooled than the leeward side, because it is better scrubbed by the passing air. In the present arrangement, the air exiting the cooling ducts on the leeward side will experience less air resistance, and
15 therefore air will flow through the ducts on the leeward side more quickly than through the ducts on the windward side. This will have the effect of reducing the temperature differential between the windward and leeward sides of the pole. This can reduce the differential thermal growth of the copper and reduce the stress built up due to linear and radial expansion. This in turn reduces the potential for micromovement
20 of the windings which reduces the likelihood of turn-to-turn or layer-to-layer DC short circuits.

Figure 7 shows a cut away part of the rotor and stator in a rotating electrical machine. As can be seen in Figure 7, air passes through ducts 32 in the rotor windings 22, and
25 out through ducts 52, 54 in the stator 50.

Figure 8 shows an alternative arrangement of a strip of material which forms a cooling duct. In this arrangement a strip 60 is made from a thermally conductive material, and extends into the air stream below the windings 62. In this arrangement
30 no bridging members, or a reduced number of bridging members, are provided. By arranging the strip 60 to extend into the air flow, additional cooling of the windings may take place by thermal conduction through the strip.

In the arrangement of Figure 8 the strip 60 is made of metal, such as copper or aluminium, and an insulating material 64 is provided between the strip 60 and the windings 62, in order to reduce the risk of a short circuit in the windings. The strip 60 is not insulated in that part which is outside of the windings, to enable effective cooling. Alternatively the strip may be made of a material which is thermally conductive but not electrically conductive, in which case it may be possible to dispense with the insulation 64. This may also be the case if the windings are well insulated.

5 A plurality of strips 60 may be provided as required. The parts of the strips which extend into the air stream may be finned or otherwise shaped so as to maximise cooling.

The present invention allows the rotor to be cooled at the centre of the rotor windings under the pole shoe, which is typically the hottest part of the rotor. This can allow the rating of the machine to be increased, if rating is limited by rotor temperature rise. Furthermore, by cooling the windings, the temperature rise in the windings is reduced thereby lowering the winding resistance. This can reduce the copper losses in the windings, thereby increasing the efficiency of the machine.

15 20 While preferred features of the invention have been described with reference to specific embodiments, it will be appreciated that variations are possible without departing from the scope of the invention. For example, the rotor may have a different number of poles, such as six, eight or more. Cooling fluids other than air could be used, such as inert gases or liquid coolants such as oil or water. Cooling ducts may additionally be provided in other parts of the windings, such as in the outhangs, and other cooling techniques, such as finned wedging devices, may be used in addition to the techniques of the present invention.

CLAIMS

1. A rotor for a rotating machine, the rotor comprising a plurality of salient poles, at least one of the poles comprising a main pole body on which is wound
5 at least two layers of windings, and a pole shoe arranged at least partially to overlap the windings in a circumferential direction so as to retain the windings, wherein a cooling duct is provided between two layers of windings in an area which is overlapped by the pole shoe.
- 10 2. A rotor according to claim 1, wherein the duct is formed by providing a strip of material between two layers of windings.
3. A rotor according to claim 2, wherein the strip is made from an electrical insulator.
- 15 4. A rotor according to any of the preceding claims, wherein the strip is made from a thermally conductive material, and part of the strip extends out of the windings.
- 20 5. A rotor according to claim 4, wherein the strip is made of metal.
6. A rotor according to claim 5, wherein a part of the strip inside the windings is insulated, and a part of the strip outside the windings is not insulated.
- 25 7. A rotor according to any of claims 2 to 6, wherein the strip extends in a substantially radial direction.
8. A rotor according to any of claims 2 to 7, wherein the strip is an individual piece.
- 30 9. A rotor according to any of claims 2 to 7, wherein the strip is part of a matrix of strips.

10. A rotor according to any of claims 2 to 9, wherein the strip is positioned at a location between 25% and 75% across the windings in a circumferential direction, and preferably between 50% and 75% across the windings.

5 11. A rotor according to any of the preceding claims, wherein a plurality of ducts are provided between the layers of windings.

12. A rotor according to any of the preceding claims, wherein the duct has an entry path and an exit path.

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13. A rotor according to claim 12 wherein the entry path is located at a point closer to the axis of rotation than the exit path.

14. A rotor according to claim 12 or 13, wherein the entry path is located on a bottom surface, in a radial direction, of the windings.

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15. A rotor according to claim 14, wherein the rotor has a channel under the bottom surface of the windings, which channel is in communication with the duct.

20 16. A rotor according to claim 15, wherein the channel is formed in an axial direction through a bridging member which bridges two adjacent poles and abuts the bottom of the windings.

25 17. A rotor according to claim 16, wherein the rotor is formed from a plurality of laminations, and in each lamination bridging members are provided between some adjacent poles, but not others.

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18. A rotor according to any of claims 12 to 17, wherein the exit path is located on a top surface, in a radial direction, of the windings.

19. A rotor according to any of claims 12 to 18, wherein a groove is provided in the pole shoe, which groove provides the exit path.

20. A rotor according to any of the preceding claims, wherein the rotor is formed from a plurality of laminations, and one or a group of laminations is recessed at a part of the pole shoe which abuts the windings, with respect to the other laminations.

5

21. A rotor according to any of the preceding claims, wherein the rotor is formed from a plurality of laminations, each of the laminations being the same shape, and one or a group of laminations is rotated with respect to the other laminations.

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22. A rotor according to claim 21 wherein, in each lamination, at least one of the poles has a different profile from at least one of the other poles.

23. A rotor according to claim 21 or 22 wherein, in each lamination, bridging members are provided between some adjacent poles, but not others.

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24. A rotor according to any of claims 21 to 23, wherein in each lamination, one pole shoe is recessed at a part of the pole shoe which abuts the windings, with respect to another pole shoe in the same lamination.

20

25. A rotor according to any of claims 21 to 24, wherein one or a group of laminations is rotated by the angle between the poles, or a multiple thereof, with respect to the other laminations.

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26. A rotor according to any of the preceding claims, wherein each pole is provided with a cooling duct.

27. A rotor according to any of the preceding claims, wherein a pole is provided with a duct on each side.

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28. A rotor according to any of the preceding claims, wherein an exit path for the duct lies at least partially in a circumferential direction.

29. A rotor according to any of the preceding claims, wherein a pole is provided with a duct on each side, and an exit path for each duct lies at least partially

in a circumferential direction, such that one exit path evacuates cooling fluid on a windward side, and one exit path evacuates cooling fluid on a leeward side, when the rotor is rotated.

5 30. A rotating electrical machine comprising a stator, and a rotor according to any of the preceding claims.

 31. A machine according to claim 30, wherein the stator has one or more ducts for evacuating the cooling fluid.

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 32. A method of manufacturing a rotor for a rotating electrical machine, the rotor comprising a plurality of salient poles, at least one of the poles comprising a main pole body and a pole shoe, the method comprising winding a first layer of windings on the pole main body, positioning a strip of material on the first layer of
15 windings, and winding a second layer of windings on top of the first layer and the strip such that a cooling duct is formed between the two layers of windings in an area which is overlapped by the pole shoe.

 33. A method of manufacturing a rotor for a rotating electrical machine,
20 the rotor comprising a plurality of salient poles, the method comprising:
 forming a plurality of laminations; and
 rotating one or a group of laminations by the angle between the poles, or a multiple thereof, with respect to the other laminations, to form a rotor body.

25 34. A method according to claim 33 wherein each lamination has an asymmetrical profile.

 35. A method according to claim 34 wherein, in each lamination, bridging members are provided between some adjacent poles, but not others.

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 36. A method according to claim 34 or 35 wherein, in each lamination, one pole shoe is recessed at a part of the pole shoe which abuts the windings, with respect to another pole shoe in the same lamination.

37. A rotor for a rotating electrical machine, the rotor comprising a plurality of salient poles, wherein the rotor has a rotor body which is formed from a plurality of laminations each having the same profile, in which one or a group of laminations has been rotated by the angle between the poles, or a multiple thereof,
5 with respect to other laminations.

38. A rotor substantially as described herein with reference to and as illustrated in the accompanying drawings.

10 39. A method of manufacturing a rotor substantially as described herein with reference to the accompanying drawings.



For Innovation

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Application No: GB0508330.8

Examiner: John Cockitt

Claims searched: 1-32

Date of search: 23 August 2006

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1- 4,7,8,10- 15,18,19 at least	JP2001211607 A SHINKO - see figs
X	1- 3,7,8,10- 15,18,19 at least	US3846651 A WESTINGHOUSE - see whole document
X	1 at least	FR2465349 A ALSTOM - see radial cooling spaces eg fig4

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

H2A

Worldwide search of patent documents classified in the following areas of the IPC

H02K

The following online and other databases have been used in the preparation of this search report

ONLINE: WPI, EPODOC