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United States Patent Application Publication	20250260282
Kind Code	A1
Publication Date	August 14, 2025
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ROTOR STRUCTURE

Abstract

A rotor structure comprises core laminations, two ring covers, and a hollow shaft. The core laminations have a horizontal side with multiple equally angled lightening holes. Each ring cover has a horizontal inner surface that contacts the outermost horizontal side of the core lamination. The horizontal inner surface of the ring covers features guiding protrusions corresponding to the lightening holes. The guiding protrusions form grooves at their end surfaces that serve as oil inlets and outlets located along the inner and outer circumferential surfaces of the ring covers, respectively. The core laminations and the ring covers are mounted on the hollow shaft, and the oil inlet of the ring cover is fluidly connected to the oil injection hole of the hollow shaft. The guiding protrusions can slow down the flow velocity centrifugally to ensure the consistency of the oil inlet and outlet.

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Family ID: **96660105**

Appl. No.: **18/438832**

Filed: **February 12, 2024**

Publication Classification

Int. Cl.: **H02K1/32** (20060101); **H02K7/00** (20060101)

U.S. Cl.:

CPC **H02K1/32** (20130101); **H02K7/003** (20130101);

Background/Summary

FIELD OF INVENTION

[0001] The present disclosure relates to a rotor structure, in particular a rotor structure with channel configurations capable of improving the temperature distribution on both side surfaces.

BACKGROUND OF THE INVENTION

[0002] During high-speed rotation, electric motor rotors generate high temperatures that require the incorporation of cooling oil passages for heat dissipation. One configuration of rotor oil passages involves injecting cooling fluid into the hollow shaft of the rotor. The rotor core is perforated with multiple holes to form axial cooling oil passages, or tubes are equipped within the holes to form the axial cooling oil passages, which have oil inlets connected to the hollow shaft and oil outlets located at the outermost core (or ring covers on both sides). Wherein the internal oil passages within the core can be positioned at any position, such as near the periphery of the permanent magnets within the core, or allowing the cooling oil to directly contact the permanent magnets.

[0003] Utilizing the centrifugal force of the rotor, cooling fluid is radially introduced into the core from the axis and then radially guided out from both sides of the core to the oil outlets. However, if there are tolerances in the assembly between the cores or discrepancies between the core and the two ring covers due to material differences, gaps may exist between the mating surfaces of the core and the core, or the core and the ring covers. Under the inertial effect during rotation, fluid expelled from the hollow shaft to the core will be thrown tangentially, flows out through the gaps between the mating surfaces, and does not effectively enter the interior of the rotor. This means that the amount of oil in multiple axial flow channels is not uniform at the same time. Furthermore, incomplete entry of the cooling fluid into the oil passages leads to uneven distribution of the internal oil, causing variations in flow velocities between different flow channels within the rotor, which affects the heat exchange rates, especially the temperature distribution at the two ring covers.

SUMMARY OF THE INVENTION

[0004] To address the foregoing shortcomings, the present disclosure provides a rotor structure comprising at least one core lamination, two ring covers, and a hollow shaft. The core lamination has a horizontal side with multiple perforations consisting primarily of multiple lightening holes and multiple magnet mounting holes. Each contour of the lightening holes is identical, equidistant from a center, and arranged at equal angles. The ring cover has a horizontal inner surface that contacts the outermost horizontal side of the core lamination. The horizontal inner surface has multiple guiding protrusions that correspond to the lightening holes one at a time with an end surface forming one portion of a groove. Some of the grooves have the other portion forming a channel inlet located on an inner circumferential surface of the ring covers, while the other portion of the other grooves forming a channel outlet located on an outer circumferential surface of the ring covers. The channel inlet and outlet are staggered around the circumferential direction. The core lamination and two ring covers are mounted on the outside of the hollow shaft, and the channel inlet of the ring cover is fluidly connected to an oil injection hole of the hollow shaft. The guiding protrusions enter the inside of the lightening holes with respect to the horizontal inner surface.

[0005] The guiding protrusions serve to block the cooling fluid leakage from the mating surfaces and reduce the flow velocity of the cooling fluid entering the core lamination channels from both sides of the ring cover, thereby increasing the time the cooling fluid stays with the shaft for effective heat exchange.

[0006] Preferably, the interior of the hollow shaft is provided with an oil duct having multiple oil guide holes distributed along the axial direction, thereby providing directionality to the cooling fluid within the hollow shaft and limiting the flow rate.

[0007] Preferably, the junction between the side surface and the end surface of the guide

protrusions is formed with a rounded chamfer to facilitate smooth flow of the cooling fluid from the core to the ring cover along the junction.
[0008] Preferably, the outer contour of the guiding protrusions is spaced from the contour of the lightening holes. In this way, the guiding protrusions further have the effect of directing the leaking cooling fluid into axial cooling flow channels to stabilize the internal oil level.
[0009] Preferably, the other portion of the grooves forms a radial groove relative to the horizontal inner surface to maintain a stable flow velocity.
[0010] Preferably, the junction between the radial groove and the grooves formed on the guiding protrusions is an arcuate groove, which further slows down the flow velocity of the cooling fluid entering or leaving the radial groove.
[0011] Preferably, a portion of the side surface of the guiding protrusions facing the hollow shaft has an arc extending in the circumferential direction, thereby minimizing the dispersion of the cooling fluid to the outside of the flow channels.
[0012] Preferably, the number of the core laminations is multiple and offset along the circumferential direction.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0013] FIG. **1** is a schematic diagram of the rotor structure;
[0014] FIG. **2** is an exploded view of the rotor structure;
[0015] FIGS. **3** and **4** are schematic diagrams of the cooling oil passages;
[0016] FIG. **5** is a schematic diagram of part of one side of the rotor core and the ring cover;
[0017] FIG. **6** is a schematic diagram of the cooling oil passage in the outlet groove; and
[0018] FIG. **7** is a schematic diagram of the cooling oil passage in the inlet groove.
DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS
[0019] Refer to FIGS. **1** through **7** for an illustration of the internal structure of the rotor. The rotor structure comprises a rotor core **20**, ring covers **40**A, **40**B, and a hollow shaft **50**. The rotor core **20** includes at least one core lamination **21**. The hollow shaft **50** has an outwardly expanded base **55** on one side and an outer circumferential surface **56**.
[0020] The ring cover **40**A, the rotor core **20**, and the ring cover **40**B are sequentially mounted on the outer circumferential surface **56** of the hollow shaft **50**. The inner circumferential surface of the ring cover **40**A is confined at an inner side of the base **55**. The outer circumferential surface **56** matches the inner circumferential surface of the core lamination **21**, thereby allowing the core lamination **21** to rotate synchronously with the hollow shaft **50**. The matching structure may include, for example, positioning the inner circumferential surface of the core lamination **21** with convex rails **215** to fit into corresponding axial grooves **561** of the outer circumferential surface **56** to aid in alignment. An end locking fixture **10** is locked from the other side of the hollow shaft **50** to clamp the ring cover **40**B, thereby forming a cooling oil passage within the rotor.
[0021] The core lamination **21** has horizontal and parallel core faces **211**, **212** on both sides with multiple perforations penetrating the core faces **211**, **212**. The perforations include multiple lightening holes **23** and multiple magnet mounting holes **24**. Each lightening hole **23** has the same contour, is equidistant from a center, and is arranged at equal angles. In addition to reducing the weight of the rotor, the lightening holes **23** also define axial flow channels within the core. In contrast to the lightening holes **23**, the multiple magnet mounting holes **24** are located away from the center and are used to accommodate permanent magnets **30**.
[0022] In contrast to creating the separate lightening holes (forming hollow passages) and flow channel holes (forming flow channels) within the core, in this embodiment the lightening holes are used directly to form the flow channels. This increases the size of the lightening hole flow channels

and oil storage, reduces the flow rate of the cooling fluid at the same injection rate, and facilitates efficient heat exchange within the core. In a preferred embodiment, the lightening holes **23** are placed as close as possible to the magnet mounting holes **24**, allowing the cooling fluid to carry away the high temperature of the permanent magnets **30**.

[0023] In comparison to the prior art, although the flow channel holes connected to the magnet mounting holes are provided around the magnet mounting holes, allowing direct contact of the cooling fluid with the permanent magnets, which also allows the temperature to be cooled. However, if these flow channel holes are too small, excessive flow resistance will result. At the junction of the radial and axial flow channels, it is difficult for the cooling fluid to enter or exit the small-sized flow channel holes only by the centrifugal force during rotation. The overall flow velocity of the cooling oil passages is also uneven, which affects the overall temperature distribution of the rotor. In the prior art, if there are gaps in the mating surfaces of adjacent components, the actual amount of the cooling fluid entering the cooling oil passages may be much less. This reduced amount may only occur when the rotor is stationary and the cooling fluid cannot immediately flow out of the oil outlets on both sides of the core, causing the cooling fluid to pool and then enter the oil inlets of the core. Therefore, if the cooling fluid flow is not continuous during operation, the heat exchange efficiency will be limited.

[0024] In this embodiment, the structures of the ring covers **40**A and **40**B are identical. Taking ring cover **40**A as an example, it has a horizontal inner surface **401** and an outer surface **402**. The inner surface **401** contacts the outermost core face **212** of the rotor core **20**, while the outer surface **402** is placed away from the rotor core **20** and faces outwardly. The horizontal inner surface **401** of the ring cover **40**A has multiple guiding protrusions **41**, which correspond in number and location to the multiple lightening holes **23**. When the rotor assembly is completed, the guiding protrusions **41** enter the interior of the lightening holes **23** relative to the horizontal inner surface **401**. This means that the guiding protrusions **41** are located inside of an inner circumferential wall **231** formed in the lightening holes **23** of the core lamination **21**, thereby enabling synchronous rotation of the ring cover **40**A with the core lamination **21** (the hollow shaft **50**)

[0025] Each of the guiding protrusions **41** has a side surface **411** and an end surface **412**. Some of the guiding protrusions **41** form a portion of an inlet groove **451**, while others form a portion of an outlet groove **452**. The inlet groove **451** is recessed along the end surface **412** and the side surface **411** of the guiding protrusion **41** to form a turning flow channel extending along the side surface **411** of the guiding protrusion **41** toward the axis and forming a straight radial groove **461** in the inner surface **401** of the ring cover **40**A, then a channel inlet **45**A is formed on an inner circumferential surface **403** of the ring cover **40**A. The outlet groove **452** is recessed along the end surface **412** and the side surface **411** of the guiding protrusion **41** to form a turning flow channel extending along the side surface **411** of the guiding protrusion **41** toward the outside and forming a straight radial groove **462** in the inner surface **401** of the ring cover **40**A, then a channel outlet **45**B is formed on an outer circumferential surface **404** of the ring cover **40**A.

[0026] Overall, the direction of the cooling oil passage in this embodiment is as follows: the rotor cooling fluid is injected from the axis of the hollow shaft **50**, flows into the channel inlet **45**A of the ring cover **40**A (**40**B) through oil injection holes **511**, **512** on both sides of the hollow shaft **50**, then enters the interior of the rotor core **20**, and finally guides out to the outside of the rotor through the channel outlet **45**B of the other ring cover **40**B (**40**A).

[0027] Refer to FIGS. **6** and **7**, the same is done using the ring cover **40**A as an example. When the side surface **411** of the ring cover **40**A contacts the outermost core face **212**, the inlet groove **451**, the outlet groove **452**, and the radial grooves **461**, **462** are closed. Only the channel inlet **45**A of the inner circumferential surface **403** and the oil injection hole **511** (as shown in FIG. **3**) are aligned, and the channel outlet **45**B of the outer surface **402** faces outward. The channel inlet **45**A and the channel outlet **45**B of the ring cover **40**A are staggered along the circumferential direction. The channel inlet **45**A of the ring cover **40**A and the channel outlet **45**B of the ring cover **40**B are fluidly connected to the same axial cooling oil passage, and the channel inlet **45**A of the ring cover **40**B and the channel outlet **45**B of the ring cover **40**A are fluidly connected to the same axial cooling oil passage. Wherein the channel inlet **45**A of the ring cover **40**A is aligned with the oil injection hole **511**, and the channel inlet **45**A of the ring cover **40**B is aligned with the oil injection hole **512** (as shown in FIG. **3**), thereby allowing the flow directions of adjacent flow channels along the circumferential direction of the rotor core **20** to be staggered to ensure a more uniform temperature distribution of the entire rotor core **20**.

[0028] Apart from the inlet groove **451** and the outlet groove **452** formed on the surface of the guiding protrusion **41**, the multiple guiding protrusions **41** projected on the horizontal inner surface **401** are arranged at equal angles along the circumference, and the remaining surfaces (the side surface **411**) of the guiding protrusion **41** can block the cooling fluid from infiltrating the horizontal mating surfaces **401**, **212** between the core lamination **21** and the ring cover **40**A, thereby reducing the dispersion of the cooling fluid to the outside of the flow channels. The cooling fluid can only accumulate on the horizontal mating surface in front of the side surface **411**, making it easier for the cooling fluid to enter the channel inlet **45**A and stabilize the internal oil level.

[0029] Furthermore, according to the Bernoulli principle, velocity is inversely proportional to pressure. When high-speed fluid hits the side surface **411** of the guiding protrusion **41** of the ring cover **40**A or the inlet groove **451** during rotor rotation, the instantaneous speed of the fluid decreases, which increases the pressure of the fluid. This increased pressure prolongs the time that the fluid remains near the axis, which greatly increases the heat exchange with the axis, thereby maintaining a stable oil level in the flow channels.

[0030] Refer to FIG. **5**. In addition to the above structure, in a preferred embodiment, the contour of the guiding protrusion **41** corresponds to the contour of the lightening hole **23**. A portion of the side surface **411** of the guiding protrusion **41** facing the hollow shaft **50** has an arc **413** distributed in the circumferential direction, which can minimize the dispersion of the cooling fluid to the outside of the flow channel as much as possible. The corresponding contour refers to the contour and size of the guiding protrusion **41** being exactly the same as the contour and size of the lightening hole **23**, or the contour shapes being the same but with different sizes.

[0031] In other embodiments, as shown in FIG. **2**, the interior of the hollow shaft **50** is equipped with an oil duct **53**, and the oil duct **53** has multiple oil guide holes **531** distributed along the axial direction, thereby providing directionality to the cooling fluid within the hollow shaft **50** and limiting the flow rate, reducing the instantaneous rotational speed generated by the rotor during rotation, which changes the fluid velocity of the oil entry.

[0032] In other embodiments, in addition to the structure described above, the junction between the side surface **411** and the end surface **412** of the guiding protrusion **41** may also be formed with a rounded chamfer **414**. This allows the cooling fluid to flow smoothly along the junction as it is guided from the rotor core **20** to the ring cover **40**A (**40**B).

[0033] In other embodiments, in addition to the structure described above, there may be an interval G between the outer contour formed by the side surface **411** of the guiding protrusion **41** and the contour of the lightening hole **23**, see FIGS. **5** and **7** for specific structures. The infiltrated cooling fluid is blocked by the side surface **411** of the guiding protrusion **41** and reintroduced into the lightening hole **23** to keep the oil level within the flow channel stable. Since the pressures on both sides of the channel outlet **45**B are more consistent, the oil outflow on both sides is improved so that the temperature of the rotor on both sides is more uniform.

[0034] In other embodiments, in addition to the structure described above, the junction between the radial groove **461** and the oil inlet groove **451** formed in the guiding protrusions **41** or the junction between the radial groove **462** and the oil outlet groove **452** formed in the guiding protrusions **41** may also be formed with a concave arcuate groove **471**. This further reduces the radial flow velocity into/out of the radial groove **461** (the radial groove **462**), prolongs the time that the cooling fluid remains in the lightening hole **23**, and facilitates thorough heat exchange.

[0035] In other embodiments, as shown in FIG. **1**, the number of core laminations **21** of the rotor core **20** is multiple, and the multiple core laminations **21** are stacked and positioned along the axial grooves **561** of the outer circumferential surface of the hollow shaft **50**. This allows the corresponding lightening holes **23** to be stacked along the axial direction, forming multiple non-overlapping channels inside the rotor. However, the structure of the previous embodiment may also be a rotor core **20** composed of a single core lamination **21**, with the horizontal inner surfaces **401** of the two ring covers **40**A, **40**B attached to the front side core face **211** and the rear side core face **212** of the core lamination **21**, respectively.
[0036] In other embodiments, in addition to the structure described above, the core laminations **21** of different layers may be offset at equal angles along the circumferential direction, and the lightening holes **23** of the core laminations **21** may also be offset along the circumferential direction to form inclined flow channels of the axial cooling oil passages.
[0037] In this embodiment, the radial grooves **461** of the ring cover **40**A connected to the same axial cooling oil passage are not on the same line as the radial grooves **462** of the ring cover **40**B. However, in other embodiments, the radial grooves **461** (the inlet groove **451**) of the ring cover **40**A connected to the same axial cooling oil passage may also be aligned with the radial grooves **462** (the outlet groove **452**) of the ring cover **40**B.

Claims

1. A rotor structure comprising: at least one core lamination having a horizontal side and multiple perforations, wherein the perforations consist of multiple lightening holes and multiple magnet mounting holes, and each contour of the lightening holes is identical, equidistant from a center, and arranged at equal angles; two ring covers each having a horizontal inner surface contacting an outermost horizontal side of the core lamination, the horizontal inner surface having multiple guiding protrusions corresponding to the lightening holes one at a time, with an end surface forming one portion of a groove, some of the grooves having the other portion forming a channel inlet located on an inner circumferential surface of the ring covers, while the other portion of the other grooves forming a channel outlet located on an outer circumferential surface of the ring covers, the channel inlet and the channel outlet being staggered around a circumferential direction; and a hollow shaft where the core lamination and the two ring covers are mounted on an outside of the hollow shaft, and the channel inlet of the ring covers is fluidly connected to an oil injection hole on the hollow shaft, wherein the guiding protrusions enter an inside of the lightening holes with respect to the horizontal inner surface.
2. The rotor structure according to claim 1, wherein an interior of the hollow shaft is provided with an oil duct having multiple oil guide holes distributed along an axial direction.
3. The rotor structure according to claim 1, wherein a junction between a side surface and the end surface of the guide protrusions is formed with a rounded chamfer.
4. The rotor structure according to claim 1, wherein the outer contour of the guide protrusions is spaced from the contour of the lightening holes.
5. The rotor structure according to claim 1, wherein the other portion of the grooves forms a radial groove relative to the horizontal inner surface.
6. The rotor structure according to claim 5, wherein the junction between the radial groove and the grooves formed on the guiding protrusions is an arcuate groove.
7. The rotor structure according to claim 1, wherein a portion of a side surface of the guiding protrusions facing the hollow shaft has an arc extending in the circumferential direction.
8. The rotor structure according to claim 1, wherein the number of the core laminations is multiple and offset along the circumferential direction.