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(54) **A SLIP RING FROM DIFFERENT MATERIALS**

(57) The present disclosure relates to a slip ring for an electric machine to transfer current from a current source to a rotor of an electric machine. It is an object of the invention to provide a slip ring with improved properties against the state of the art. Disclosed is a slip ring for an electric machine with a cylindrical body made out of a first material with an electrical conductivity in the range of $1*10^6$ S/m to $100*10^6$ S/m and a thermal conductivity in the range of 50 W/mK to 500 W/mK, with a cover out of a second material which encompasses the cylindrical body.

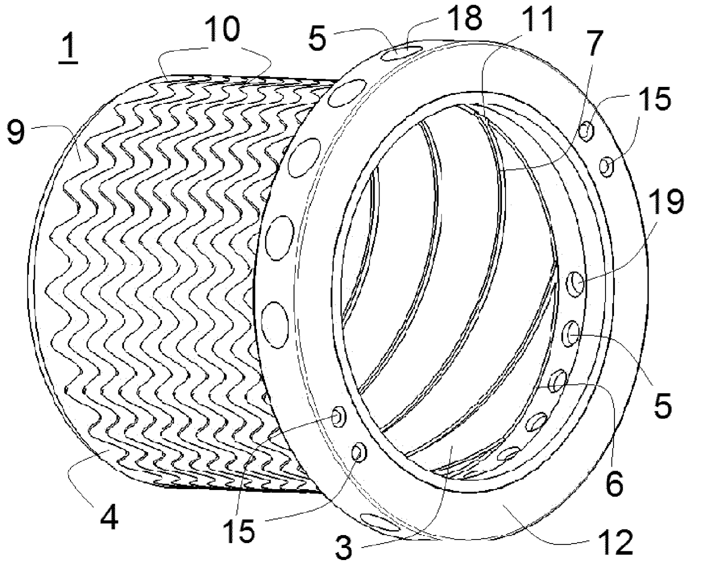

FIG. 1

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Description

Technical Field

[0001] The present disclosure relates to a slip ring for an electric machine to transfer current from a current source to a rotor of an electric machine.

[0002] The electric machine is in particular a rotating electric machine such as a synchronous generator to be connected to a gas or steam turbine, then referred to as turbogenerator, or a synchronous generator to be connected to a hydro turbine, a hydro generator, or an asynchronous generator or a synchronous or asynchronous electric motor or also other types of electric machines, as rotary transformers.

BACKGROUND

[0003] Electric machines are excited with an electric excitation current to generate the necessary magnetic field in the winding coils. In specific configurations the excitation current is supplied to the winding coils or windings of the rotor of the electric machine, then referred to as rotor current. In static exciters, rotor current generated outside the machine is transferred by a set of brushes to the rotor windings. The current flowing in the stationary brushes is transferred to the rotor winding via at least one ring mounted onto the rotational shaft. This at least one ring is commonly denominated as slip ring in this technical field. The slip ring is commonly an elongated cylindrical tube made out of steel or copper-alloys. The slip-ring material ensures a high wear resistance, high mechanical strength for high speed applications and an adequate electrical conductivity from the brushes to the rotor windings. In particular the material stability of steel makes it the material of choice for this application although other properties are not optimum, as the electrical and thermal conductivity.

SUMMARY

[0004] It is an object of the invention to provide a slip ring with improved properties against the state of the art. This object is solved with the features of a slip ring according to the independent claim.

[0005] According to the invention a slip ring for an electric machine is disclosed composed of a cylindrical body made out of a first material with a high electrical and thermal conductivity in the range of 50 to 500W/mK, with a cover from a second material which encompasses the cylindrical body.

[0006] Further examples of the invention are described in the independent claims.

[0007] In one example of the invention the first material is copper, a copper alloy, an aluminium or an aluminium alloy. Alternatively, the first material comprises a carbon nanotube composite or graphene. These first materials ensure a high electrical and thermal conductivity to transfer current from the brushes through the slip ring and enhance the heat transfer within the body.

[0008] In an example of the invention the cover is conjoined mechanically and electrically to the cylindrical body by bolts, threads, welding, seam welding or friction welding, brazing, plasma spraying, or heat-shrinking. The cover to apply to the cylindrical body can be a massive body or a bulk material to harden at the cylindrical body accordingly.

[0009] In another example of the invention the second material of the cover is steel or a ferroalloy with a mechanical stability of more than 250MPa and a thickness between 1mm to 60mm covering the cylindrical body out of the first material. This second material guarantees the required high wear-resistance and enhanced mechanical properties for long-term operation of the slip ring. The friction between stationary brushes and the rotary surface of the cylindrical body as well as passing currents introduce dissipation heat in the range of several kW, which increases the temperature of the involved parts. In order to keep the temperature of the slip ring within a predefined range, some cooling measures are needed. These cooling measures comprise a cooling medium which flows out of a medium with lower temperature compared to the slip ring removing the dissipative heat.

[0010] In a further example of the invention and in order to improve the autonomous cooling of the slip ring, a multitude or at least one radially inclined opening or bore are positioned in the cylindrical body. The inclined openings can also be fixed as separate parts onto the former parts or be a part of the aforementioned steel cylindrical body. The radially inclined opening or bore create a cooling medium charge with a cooling medium which is commonly air. The inclined openings are connected with each other via further ducts acting as manifold equalizing the pressure and therefore the discharge flow rate of the cooling medium. The openings or bores are fabricated with known techniques within the cylindrical body of the slip ring. The openings or bores serve as cooling medium channels. As a general rule, the higher the cooling rate, the higher the possible current- and speed rate of a slip ring.

[0011] In further examples of the invention the cooling medium which has passed the openings in the slip ring passes an annular first groove and a second groove along the slip ring. A third groove or third grooves are provided at the outer side or outer wall of the slip ring to remove or absorb air-cushions between the slip ring and brushes touching the outer wall in operation.

[0012] In a further example the second groove on the inner and/or outer surface of the cylindrical body has a spiral, helical, or wavy course.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Further characteristics and advantages will be more apparent from the description of a preferred but non-exclusive embodiment of the slip ring, illustrated by way of non-limiting example in the accompanying drawing, in which:

Fig. 1 shows a perspective view of a slip ring composed of a cylindrical body made from a first material and a cover from a second material which encompasses the cylindrical body, with openings at the edge of the cylindrical body, first and second grooves in the inside of the cylindrical body, and third grooves along the circumference of the outer wall of the cover according to an example of the invention;

Fig. 2 shows a side view of a slip ring similar to Fig. 1 according to an example of the invention, with a helical third groove at the cover around the cylindrical body;

Fig. 3 shows a schematic partly cut view of an opening in the cylindrical body with inclined inner walls inside the openings, and arrows illustrating the flow direction of the cooling medium and the rotating direction of the slip ring;

Fig. 4 shows a schematic cut side view of the cylindrical body with one opening according to Fig. 3 to illustrate the curve of the inner walls of the opening, and an extension at one edge of the opening to enhance the flow rate of the cooling medium;

Fig. 5 shows a pair of opposed slip rings similar to Fig. 2 with openings and arrows illustrating the flow of cooling medium into the slip rings and out of the slip rings.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0014] With reference to the figures, these show two views of two different slip rings 1, a schematic view of an edge of the cylindrical body 3 with openings 5 with inclined inner walls 8, and a pair of slip rings 1, wherein like reference numerals designate identical or corresponding parts throughout the several views.

[0015] Fig. 1 shows a perspective view of a slip ring 1 for use in an electrical machine, in particular a turbogenerator. The slip ring 1 is suitable to be shrunk to a shaft with at least one insulation material in-between. One possibility is to heat-shrunk the slip-ring 1 in a temperature range of less than 300°C. The slip ring 1 is composed of a cylindrical body 3 made out of a first material with a high electrical and thermal conductivity. This first material is copper or a copper alloy. The cylindrical body 3 from the first material preferably has a thickness between 5mm and 50mm. The copper alloy is for example Cu-Nb, copper-niobium, Cu-Ag, copper-silver, CuCrTiSi-alloys, copper-chrome-titanium-silicon, low alloyed copper, Cu-Be, copper-beryllium, or Corson type alloys. The choice of the first material is a trade-off between the quantities of yield strength and electrical conductivity. The cylindrical body 3 is at least partly encompassed by a cover 4 from a second material, preferably high strength steel. The cover 4 is mounted at the cylindrical body 3 by a method like heat-shrunk, for example in the temperature range of 50°C to 450°C, fusing, clamping, coating, spraying, sputtering or other means. In the example of Fig. 1 the cover 4 is a cylindrical ring which is shrunk onto the cylindrical body 3 along the whole length except for a flange 12 at the edge of the cylindrical body 3. The flange 12 has fixing bores 15 for fixing the slip ring 1 to other current conducting members as part of the excitation current carrying system. The flange 12 is optional. The cover 4 provides further mechanical properties to the slip ring 1, especially a high tensile strength. In this example the cover 4 is a cylindrical ring from a high tensile strength material heat-shrunk with an elevated temperature, up to 450°C. The cover 4 from the second material preferably has a thickness of 1mm to 60mm and a high tensile strength or mechanical stability of more than 300MPa. The combination of the two different materials provides a slip ring 1 with improved properties tailored to its inherent task, good electrical and thermal conduction combined with high wear resistance. The cylindrical body 3 from the first material has a higher electrical conductivity than common steel slip rings, whereas the cover 4 from the second material forming a thin sleeve provides a sufficient mechanical stability, tensile strength and wear resistance to the slip ring 1. The resulting slip ring 1 provides equal mechanical stability and electrical conductivity, compared to a single alloy design with reduced volume and enhanced cooling properties. This advantage is beneficial to reduce either the size of the slip ring 1, to enlarge the adjacent rotary shaft diameter, or to increase the current carrying rate making it suitable for a higher power transmission. By keeping the original rotor shaft diameter, the reduced slip ring size will lead to lower circumvention speed, therefore lower dissipation heat and an extended brush gear life time. The cylindrical body 3 has openings 5 at the edge which project through the whole thickness of the cylindrical body 3. The openings 5 have a circular cross-section in this example, further cross-sections can be designed, e.g. openings 5 with a rectangular cross-section. The openings 5 are designed at the edge of the cylindrical body 3. The openings 5 are not symmetrical and have different shapes and sizes in the radial direction. The openings 5 are defined with intakes 18 with specific sizes and shapes and with outlets 19 with different specific shapes and sizes. As inner walls 8 of the openings 5 are inclined, the distribution of the

[0016] Upon rotation, a cooling medium, e.g. air, flows through the openings 5 to cool the slip ring 1. In order to increase the heat exchange-rate of the slip ring 1 the temperature gradient between the cooling medium and the slip ring 1 can be increased by means of a lowered temperature of the cooling medium or by increasing the flow rate of the cooling medium. Both methods increase the power consumption of the corresponding system. On the contrary to known methods of straight axial cooling ducts in the slip ring 1, the described design in this example relies on spiral-shaped ducts which enlarge the heat exchange surface and enhance the dynamic characteristic compared to the state of the art. This is basically due to the temperature distribution, which influences the shape of the slip-ring rotary surface. An uneven or non-uniform temperature distribution is inherently given with axial straight bores. Spirally shaped second grooves 7 or ducts depicted in Fig. 1 on the inner surface of the highly conductive cylindrical body 3 enhance the temperature distribution and makes the temperature distribution more equalized, therefore improve the dynamic characteristic of such a design. The second groove 7 can also be placed on the outer surface of the cylindrical body 3 (not shown). The cooling medium enters the slip ring 1 at the outer face through the openings 5 through the intakes 18 of the openings 5 and flows through the openings 5 to the inside of the slip ring 1 where the cooling medium leaves the openings 5 through the outlets of the openings 5. At the inside of the cylindrical body 3 adjacent to the openings 5 a first groove or annular groove 6 is formed in the inner face. This annular groove 6 forms a whole circle around the inner side of the cylindrical body 3. The annular groove 6 is suitable to receive and collect the cooling medium flowing from the outside through the openings 5 from the intakes 18 to the outlets 19 into the inside. The annular groove 6 serves for an even distribution of the cooling medium along the whole circumference of the inner cylindrical body 3. The annular groove 6 is connected with a second groove 7. The second groove 7 is designed at the inside of the cylindrical body 3 to transport the cooling medium from the annular groove 6 to the other end of the cylindrical body 3. The course of the second groove 7 can be differently realized. In the example of Fig. 1 the second groove 7 has a helical course along the inside of the cylindrical body 3. The course of the second groove 7 can also be designed axially with several grooves 7 or with a varying helix pitches and depths. Choosing a proper helix geometry, namely the cross-sectional dimension of the second groove 7 and the number and pitch of the second groove 7, for the specific application of the slip ring 1 leads to an optimized cooling of the slip ring 1. The cooling medium flows from one end, in Fig. 1 the right end, through the second groove 7 to the other end of the slip ring 1, in Fig. 1 the left end, and the cooling medium leaves the slip ring 1 warmed-up. The mentioned cover 4 positioned around the cylindrical body 3 has formed third grooves 10 in the outer wall 9 of the cover 4. The third grooves 10 have waveforms and run next to each other. In Fig. 1 approximately a dozen undulated third grooves 10 are formed in the outer wall 10. The undulated shape of the third grooves 10 is an alternative with the same function and performance as a helical shape. The third grooves 10 are in particular useful for high speed applications of the slip ring 1 to remove air cushions between the brushes and the slip ring 1.

[0017] Fig. 2 shows a side view of a slip ring 1 similar to Fig. 1 according to an example of the invention. The cylindrical body 3 has a flange 12 near one end similar to the example of Fig. 1. The openings 5 are again formed in the flange 12. The openings 5 have inclined inner walls 8, i.e. the inner walls 8 are not straight and parallel to each other. As depicted in Fig. 3, the inclination of the inner walls 8 of the openings 5 is such that the outlet 19 of the opening 5 at the inside is shifted by some degrees or fractions of degrees compared to the intake 18 of the opening 5 at the outside along the trajectory of the cylindrical body 3. This feature is further illustrated in Fig. 4. The third groove 10 in the outer wall 9 of the cover 4 has a helical curve in this example. The function of the third groove 10 or third grooves 10 at the outer surface is to remove an air-cushion which is inherently given in all high speed slip rings 1. The shape and sizes of such third grooves 10 may differ and is not limited to the depicted ones.

[0018] Fig. 3 shows a schematic partly cut view of an opening 5 in the cylindrical body 3 with inclined inner walls 8 inside the opening 5. The straight arrow above illustrates the flow direction of the cooling medium to and through the opening 5 to the inside of the cylindrical body 3 via an intake 18 of the opening 5. The opening 5 has a rectangular cross-section in this example. The cooling medium flows through the opening 5 to the outlet 19 of the opening 5 which is shifted from the intake 18 due to the inclined inner walls 8 of the opening 5. The bend arrow below illustrates the rotation direction of the shaft and the mounted slip ring 1. In Fig. 3 the design of the inner walls 8 of the openings 5 in relation to the rotating direction is explained. With regard to a first tip 16 at the edge of the intake 18 of the opening 5 from which the cooling medium enters at the outer face, a second tip 17 at the opposite edge of the outlet 19 at which the cooling medium leaves at the inner face is shifted. The second tip 17 is at a different plot point of the curve constituted by the cylindrical body 3 than the first spot 16. One inner wall 8 has an inclined bent-shaped, the other inner wall 8 has an inclined straight shape in this example. By the inclination of the inner walls 8 a higher flow rate of the cooling medium is accomplished to cool the slip ring 1. This is subject to rotation velocity, allowed dissipation loss, and the size of external ventilators.

[0019] Fig. 4 shows a schematic cut side view of the cylindrical body 3 with one opening 5 according to Fig. 3. The anticlockwise rotation direction of the slip ring 1 in operation of the electric machine is illustrated by the bended arrow below. The inflow of cooling medium into the opening 5 via the intake 18 of the opening 5 to the outlet 19 of the opening 5 is illustrated by the bended arrow within the opening 5. As can be seen the left inner wall 8 has an acute angle to the surface of the cylindrical body 3 which angle becomes steeper in the direction to the outlet 19. In addition to this example of an opening 5 an extension 20 of the cylindrical body 3 is designed at one edge of the opening 5. The extension 20 has the shape of a trapezium or trapezoid with the longer leg distant from the intake 18. The extension 20 is one-piece with the cylindrical body 3. Alternatively, the extension 20 is fixed at the cylindrical body 3. With the extension 20 an increased inflow of cooling medium is achieved. The extension 20 at the slip ring 1 can also contribute to a self-sufficient cooling of the slip ring 1 without provision of further ventilation means.

[0020] Fig. 5 shows a pair of opposed slip rings 1 similar to Fig. 2. The slip rings 1 are arranged as in operation with one slip ring 1 to transfer ingoing current and the other slip ring 1 to transfer outgoing current. The slip rings 1 have openings 5 as described above and arrows illustrating the flow of cooling medium into the slip rings 1. The vertical arrows illustrate the inflow of the cooling medium into the openings 5 with inclined inner walls 8. The horizontal arrows illustrate the outflow from the slip rings 1 after passing the annular groove 6 and the second groove 7. The cooling medium leaves the slip rings 1 out of one side span of the cylindrical body 3 towards a mid-section discharge in the electric machine. A discharge vent (not shown) is positioned in the mid-section between the both slip rings 1. Both cooling medium streams are directed to the inside towards each other. The flow direction along the slip ring 1 can also be reversed. Accordingly, the discharge vent is arranged next to the openings 5 then.

[0021] While the invention has been described in detail with reference to exemplary embodiments thereof, it will be apparent to one skilled in the art that various changes can be made, and equivalents employed, without departing from the scope of the invention. The foregoing description of the preferred embodiments of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and modifications and variations are possible in light of the above teachings or may be acquired from practice of the invention. The embodiments were chosen and described in order to explain the principles of the invention and its practical application to enable one skilled in the art to utilize the invention in various embodiments as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the claims appended hereto, and their equivalents.

REFERENCE NUMBERS

[0022]

1	slip ring
3	cylindrical body
4	cover
5	opening or openings
6	annular groove
7	second groove
8	inner wall
9	outer wall
10	third groove or third grooves
12	flange
16	first tip
17	second tip
18	intake
19	outlet
20	extension

Claims

1. A slip ring (1) for an electric machine with a cylindrical body (3) made out of a first material with an electrical conductivity in the range of $1*10^6$ S/m to $100*10^6$ S/m and a thermal conductivity in the range of 50 W/mK to 500 W/mK, with a cover (4) out of a second material which encompasses the cylindrical body (3).

2. The slip ring (1) according to claim 1, **characterized in that** the first material is copper, a copper alloy, an aluminium or an aluminium alloy.

3. The slip ring (1) according to claim 1, **characterized in that** the first material comprises a carbon nanotube composite or graphene.

4. The slip ring (1) according to claim 1, **characterized in that** the cylindrical body (3) is fixed to a rotary shaft with electrical insulation material in-between.

5. The slip ring (1) according to claim 1, **characterized in that** the cover (4) is conjoined mechanically and electrically to the cylindrical body (3) by bolts, threads, welding, brazing, plasma spraying or heat-shrinking.

6. The slip ring (1) according to claim 1 or 5, **characterized in that** the second material of the cover (4) is steel or a ferroalloy with a mechanical stability of more than 100MPa and a thickness between 1mm to 60mm covering the cylindrical body (3) out of the first material.

7. The slip ring (1) according to claim 1, **characterized in that** the cylindrical body (3) has radially inclined openings (5) around the circumference near the edge for a cooling medium to pass through.

8. The slip ring (1) according to claim 1, **characterized in that** the cylindrical body (3) has an annular groove (6) on the inner and/or outer surface along the circumference for passing of a cooling medium.

9. The slip ring (1) according to claim 1, **characterized in that** the cylindrical body (3) has a through-going

second groove (7) on the inner and/or outer surface to transport the cooling medium from one edge to the other edge of the slip ring (1).

10. The slip ring (1) according to claim 9, **characterized in that** the second groove (7) on the inner and/or outer surface of the cylindrical body (3) has a spiral, helical, or wavy course.

11. The slip ring (1) according to claim 1, **characterized in that** the cover (4) has at least a third groove (10) along the circumference of the outer wall (9) to remove air-cushions between the brushes and the slip-ring (1).

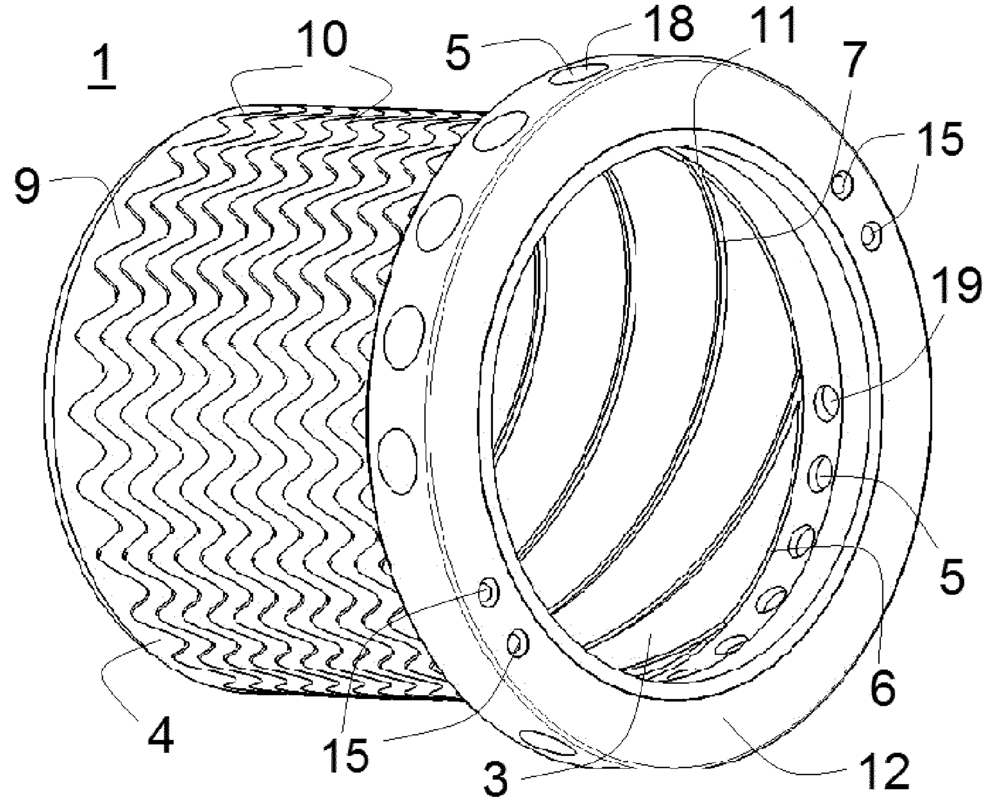

FIG. 1

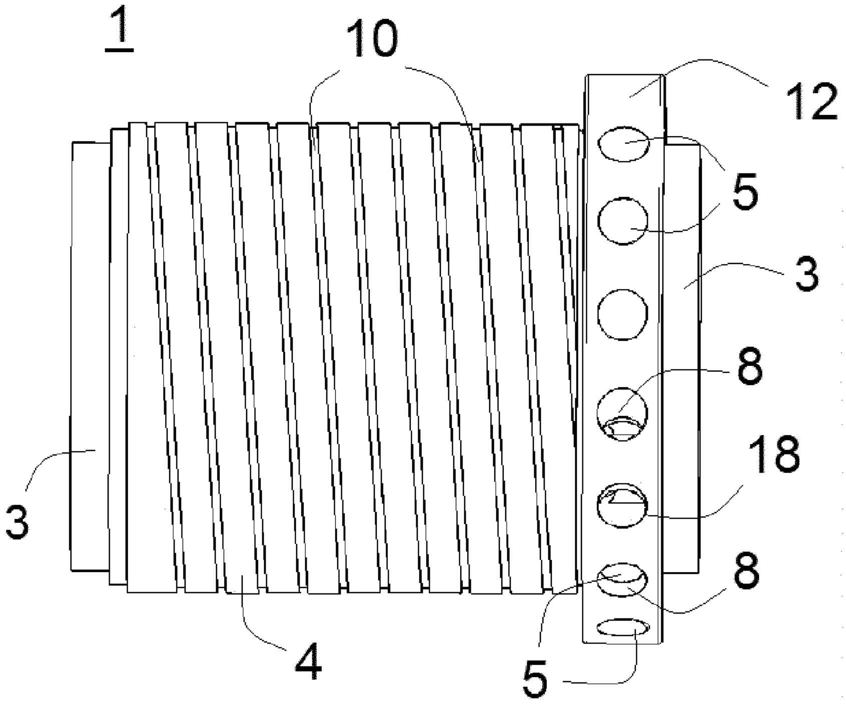

FIG. 2

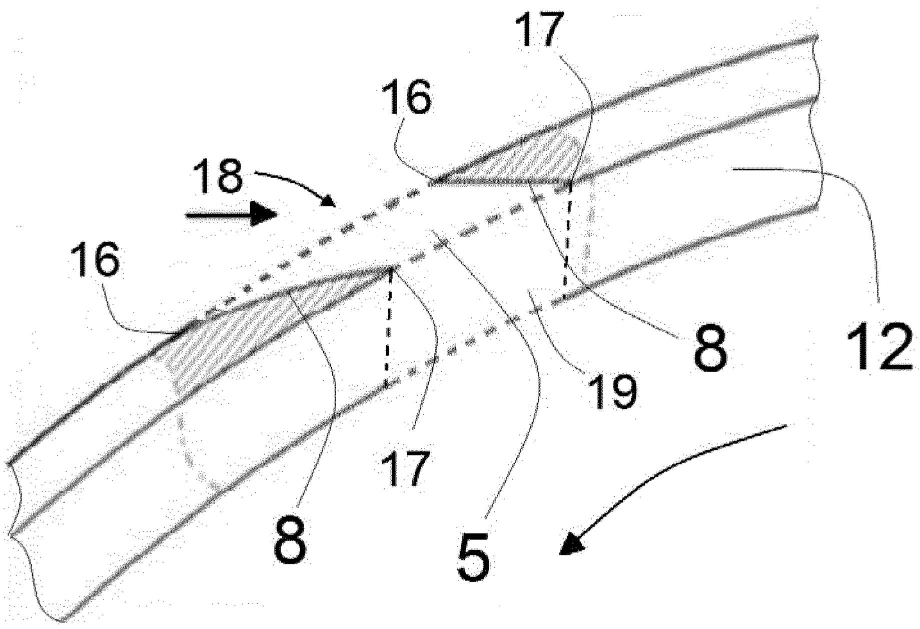

FIG. 3

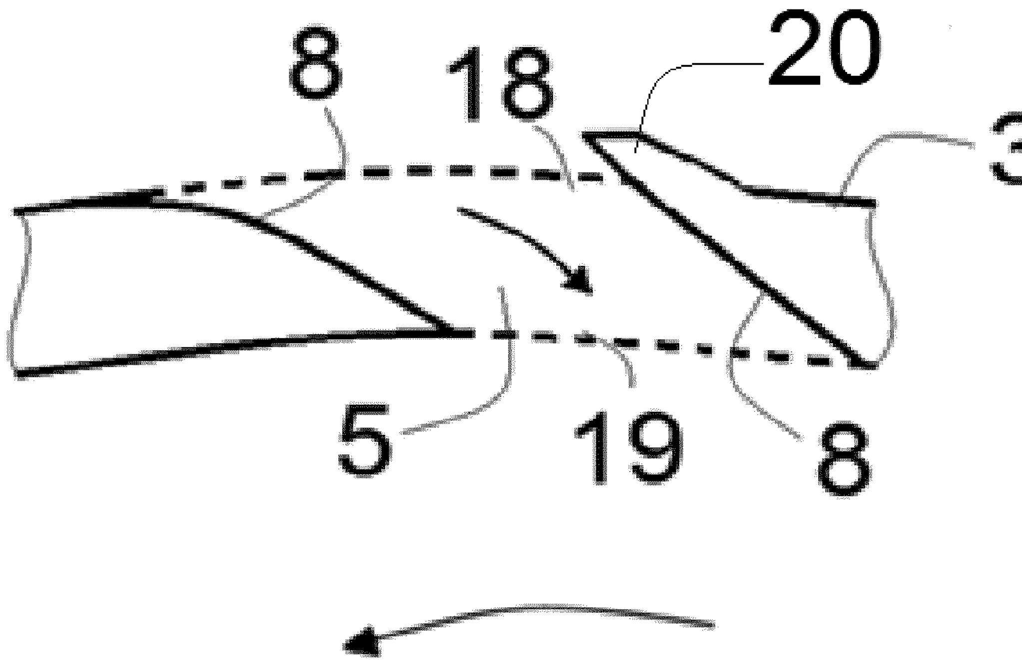

FIG. 4

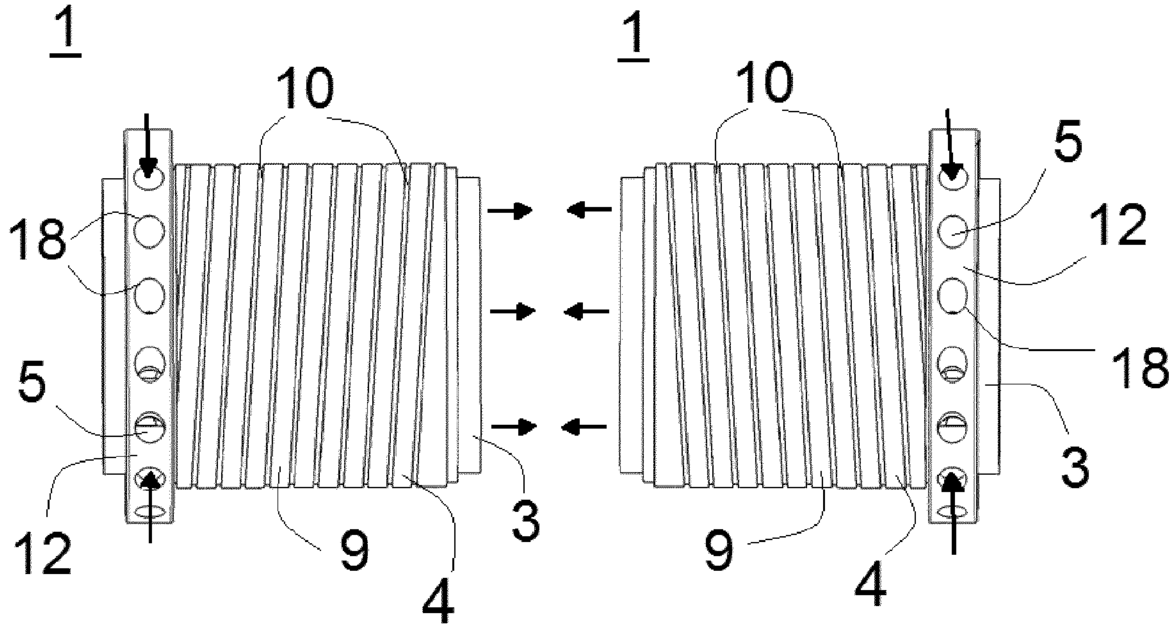

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 15 19 8619

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2

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	11 May 2016	Ferreira, João

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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