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(54) STATOR ASSEMBLY FOR A RADIAL-AXIAL EXPANSIONSTAGE OF A STEAM TURBINE

(57) A stator assembly for a radial-axial expansion stage of a steam turbine includes: an anchoring ring (13) extending around an axis (A); a guide ring (15), extending around the axis (A); a plurality of tangential stator vanes (17), each having a respective airfoil (18) connected to respective portions of the anchoring ring (13) and of the guide ring (15), the stator vanes (17) being arranged around the axis (A) and configured to tangentially accelerate a steam flow entering from the outside toward the inside of the stator assembly. The stator vanes (17) are formed in a single piece with the respective portions of the anchoring ring (13) and of the guide ring (15).

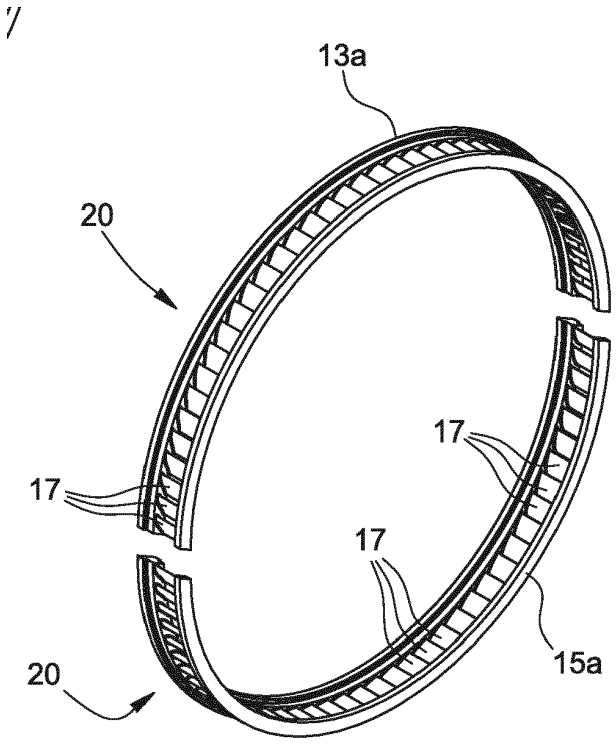

FIG. 4

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Description

PRIORITY CLAIM

[0001] *This application claims priority from Italian Patent Application No.* 102017000061762 *filed on 06/06/2017.*

[0002] The present invention relates to a stator assembly for a radial-axial expansion stage of a steam turbine.

[0003] As is known, steam turbines comprise several expansion stages wherein the thermodynamic energy of the flowing steam is converted into mechanical energy. Each stage is formed by an array of stator vanes and an array of rotor vanes. The first stage, in particular, may have different configurations depending on the design of the machine. In some steam turbines, the first stage has a radial-axial configuration: the steam entering the turbine flows through the stator vanes of the first stage in a substantially radial direction towards the inside and is axially diverted before it reaches the first array of rotor vanes. The stator vanes are shaped and arranged so as to accelerate the steam flow in the tangential direction. More precisely, the stator vanes of the radial-axial stage extend from respective anchoring portions to roof portions in a direction substantially parallel to the main axis of the steam turbine and from respective leading edges to respective trailing edges tangentially around the main axis.

[0004] The stator vanes of the first stage are individually manufactured and then mounted on the stator shell of the steam turbine. In detail, the anchoring and roof ends of each vane engage circumferential grooves formed in the shell of the steam turbine. To avoid vibrations during operation, the vanes are adjacent to each other, with the anchoring and roof adjacent surfaces touching each other, and with no clearance. Moreover, the vanes are mounted with a slight twist in the housing grooves. The interference thus generated produces a tight coupling between the vanes and reduces the risk of vibration occurrence. However, such twisting also causes high-intensity forces between the root and roof of the vanes and the respective housing grooves. In addition, the high operating temperatures favour the oxidation of the coupling surfaces between the roots and roofs of the vanes and the respective guides. Tightening by twisting and oxidation prevent free differential thermal expansion between the vanes and the shell during machine operation. As a result, the vanes are constantly subjected to stresses, which can compromise the structural integrity and reduce the service life of the vanes themselves.

[0005] Therefore, the object of the present invention is to provide a stator assembly for a radial-axial expansion stage of a steam turbine, which allows the limitations described above to be overcome, or at least mitigated.

[0006] According to the present invention, there is provided a stator assembly for a radial-axial expansion stage of a steam turbine, comprising:

an anchoring ring extending around an axis;

a guide ring extending around the axis;

a plurality of tangential stator vanes, each having a respective airfoil connected to respective portions of the anchoring ring and of the guide ring, the stator vanes being arranged around the axis and configured to tangentially accelerate a steam flow entering from the outside toward the inside of the stator assembly;

wherein the stator vanes are formed in a single piece with the respective portions of the anchoring ring and of the guide ring.

[0007] The anchoring ring and the guide ring can easily be inserted in the circumferential grooves, which, in steam turbines, are usually used to house individual vanes. Since in the present case the vanes are formed in a single piece with the anchoring ring and the guide ring, no twisting is needed to obtain an ideal tightening and effectively attenuate the vibrations. Furthermore, deformations due to thermal expansion may take place freely even in the presence of surface oxide layers, thus drastically reducing the mechanical stresses on the vanes. The risk of sudden breakage is thus reduced, while, in general, the service life of the vanes increases.

[0008] According to one aspect of the invention, the stator assembly comprises a plurality of annular sectors, each comprising a respective group of stator vanes, an anchoring ring sector and a guide ring sector, wherein the stator vanes of each sector have the respective airfoil connected to the respective anchoring ring sector and to the respective guide ring sector.

[0009] The division into annular sectors simplifies the mounting of the stator assembly on the shell of the steam turbine.

[0010] According to one aspect of the invention, the stator assembly comprises two annular sectors, each extending over an arc of 180°, wherein each group of stator vanes comprises half of the stator vanes and wherein the anchoring ring sectors and the guide ring sectors extend over arcs of 180°.

[0011] The division into only two annular sectors allows the deformations due to thermal expansion to be effectively accommodated, while maintaining an optimal distribution of the stresses and the advantages deriving from the simplicity of assembly.

[0012] According to one aspect of the invention, each annular sector is formed in a single piece.

[0013] According to one aspect of the invention, each annular sector comprises at least two respective stator vanes.

[0014] According to one aspect of the invention, the anchoring ring, the guide ring and the vanes define a substantially cylindrical region around the axis; in each vane, the airfoil has a leading edge and a trailing edge extending between the anchoring ring and the guide ring; and the airfoil of each vane has a concave side facing the outside of the cylindrical region and a convex side

facing the inside of the cylindrical region.

[0015] According to one aspect of the invention, a steam turbine comprises a radial-axial expansion stage provided with a stator assembly comprising:

an anchoring ring extending around an axis;
a guide ring extending around the axis;
a plurality of tangential stator vanes, each having a respective aerodynamic body, or airfoil, connected to respective portions of the anchoring ring and of the guide ring, the stator vanes being arranged around the axis and configured to tangentially accelerate a steam flow entering from the outside toward the inside of the stator assembly;
wherein the stator vanes are formed in a single piece with the respective portions of the anchoring ring and of the guide ring.

[0016] According to one aspect of the invention, the steam turbine comprises a shell housing a rotor rotatable about a rotation axis, the shell being provided with an anchoring circumferential groove and a guide circumferential groove; wherein the anchoring circumferential groove and the guide circumferential groove extend around the rotation axis and house the anchoring ring and the guide ring, respectively.

[0017] According to one aspect of the invention, the anchoring groove has a T-shaped cross-section and the anchoring ring has a base and a connection portion projecting from the base towards the guide ring. Moreover, the base has edges projecting radially inwards and radially outwards with respect to the connection portion, and wherein the anchoring ring is radially and axially retained inside the root guide.

[0018] The stator assembly is thus firmly locked in its seat of use and may also be removed for maintenance or replacement with relative ease. The guide ring may instead have a rectangular cross-section.

[0019] According to a further aspect of the invention, a process for manufacturing a stator assembly of a radial-axial expansion stage of a steam turbine comprises making:

an anchoring ring (13) extending around an axis (A);
a guide ring (15), extending around the axis (A);
a plurality of tangential stator vanes (17), each having a respective airfoil (18) connected to respective portions of the anchoring ring (13) and of the guide ring (15), the stator vanes (17) being arranged around the axis (A) and configured to tangentially accelerate a steam flow entering from the outside toward the inside of the stator assembly;
wherein the stator vanes (17) are formed in a single piece with the respective portions of the anchoring ring (13) and of the guide ring (15).

[0020] According to a further aspect of the invention, the process comprises obtaining a semi-finished block and making the anchoring ring (13), the guide ring (15) and the plurality of stator vanes (17) by subtractive manufacturing from the semi-finished block.

[0021] According to a further aspect of the invention, the process comprises cutting the anchoring ring and the guide ring to form a plurality of annular sectors, each comprising a respective group of stator vanes, a respective sector of the anchoring ring and a respective sector of the roof ring.

[0022] The present invention will now be described with reference to the accompanying drawings, which illustrate a non-limiting embodiment thereof, in which:

- Figure 1 is a section along an axial longitudinal plane of a steam turbine incorporating a stator assembly according to one embodiment of the present invention;
- Figure 2 is a perspective view of an enlarged detail of the steam turbine of Figure 1;
- Figure 3 is a perspective view of the stator assembly of Figure 1;
- Figure 4 is an exploded perspective view of the stator assembly of Figure 1; and
- Figure 5 is a front, partially sectioned view of the stator assembly of Figure 1.

[0023] With reference to Figure 1, a steam turbine, for convenience shown only in part, is indicated with number 1 and comprises a shell 2 and a rotor 3, which is housed inside the shell 2 so as to be rotatable around a rotation axis A. The shell 2 encloses the rotor 3 and forms a scroll 4 for receiving steam into a flow path 5 defined between the shell 2 and the rotor 3.

[0024] The shell 2 and the rotor 3 are respectively provided with arrays of axial stator vanes 7 and arrays of axial rotor vanes 8, which are arranged in succession along the flow path 5 and form a plurality of expansion stages 10 of the axial type.

[0025] An input expansion stage 11, instead, is of the radial-axial type and comprises a radial stator assembly 11a and an axial rotor assembly 11b.

[0026] The axial rotor assembly 11b comprises an array of axial rotor vanes substantially like those previously described and for this reason indicated with the same reference number 8.

[0027] The radial stator assembly 11a, which is shown in greater detail in Figures 2-5, comprises an anchoring ring 13, a guide ring 15 and a plurality of tangential stator vanes 17.

[0028] The anchoring ring 13 and the guide ring 15 are coaxial and the stator vanes 17 each have a respective airfoil 18 (Figures 2 and 5) connected to respective portions of the anchoring ring 13 and of the guide ring 15. Furthermore, the stator vanes 17 are arranged around the axis of the anchoring ring 13 and of the guide ring 15 (Figures 3-5) and are configured to tangentially accelerate a steam flow entering from the outside toward the inside of the radial stator assembly 11a. In more detail,

the anchoring ring 13, the guide ring 15 and the stator vanes 17 define a substantially cylindrical region around the axis of the anchoring ring 13 and of the guide ring. In each stator vane 17 (Figure 5), the airfoil 18 has a leading edge 18a and a trailing edge 18b extending in a substantially axial direction between the anchoring ring 13 and the guide ring 15. Moreover, the airfoil 18 of each stator vane 17 has a concave side 18c and a convex side 18d defined between the respective leading edge 18a and the respective trailing edge 18b. The concave side 18c faces the outside of the cylindrical region, whereas the convex side 18d faces the inside of the cylindrical region. The stator vanes 17 are formed in a single piece with the respective portions of the anchoring ring 13 and of the guide ring 15.

[0029] In one embodiment, the radial stator assembly 11a is defined by a plurality of annular sectors 20, each comprising a respective group of stator vanes 17, an anchoring ring sector 13a, and a guide ring sector 15a. The stator vanes 17 of each annular sector 20 have the airfoil 18 connected to the respective anchoring ring sector 13a and to the respective guide ring sector 15a.

[0030] In one embodiment, in particular, the radial stator assembly 11a comprises two annular sectors 20 (Figures 3-5), each extending over an arc of 180°. The anchoring ring sectors 13a and the guide ring sectors 15a also extend over arcs of 180° and each group of stator vanes comprises half of the total stator vanes 17. Moreover, each annular sector 20 is formed in a single piece. In further embodiments, not shown, the radial stator assembly 11a may be divided into a larger number of stator segments, for example three or four. Anyway, each annular sector comprises at least two respective stator vanes.

[0031] With reference to Figure 2, the shell 2 is provided with an anchoring circumferential groove 21 and a guide circumferential groove 22 extending around the rotation axis A. The anchoring ring 13 and the guide ring 15 are respectively housed in the anchoring circumferential groove 21 and the guide circumferential groove 22.

[0032] The anchoring circumferential groove 21 has a T-shaped cross-section and the anchoring ring 13 has a base 13b and a connection portion 13c projecting from the base 13b towards the guide ring 15. Furthermore, the base 13b has edges projecting radially inwards and radially outwards with respect to the connection portion 13c, so that the anchoring ring 13 is radially and axially retained inside the anchoring groove 21.

[0033] The guide circumferential groove 22 may have any cross section, just like the guide ring 15 (for example rectangular).

[0034] In use, a steam flow fed to the steam turbine 1 through the scroll 4 enters the flow path 5 substantially in a radial direction through the radial stator assembly 11a. The steam flow is tangentially accelerated by the stator vanes 17 of the radial stator assembly 11a and is further axially diverted before it reaches the axial rotor assembly 11b. Thereafter, the steam flow passes through the expansion stages 10 of the steam turbine 1, where part of the available thermodynamic energy is converted into mechanical energy.

[0035] The radial stator assembly 11a may be manufactured (for example and not exclusively) with any subtractive manufacturing technique starting from a semi-finished block in the form of a disk, a cylinder or more generally a plate, made of steel or even a high-nickel alloy. The manufacturing may be carried out, for example, by milling or spark erosion in order to obtain the anchoring ring 13, the guide ring 15, and the stator vanes 17 described above. Alternatively, the radial stator assembly 11a can also be manufactured with additive manufacturing techniques, in any case so that the stator vanes form a single piece with the respective portions of the anchoring ring 13 and of the guide ring 15.

[0036] The radial stator assembly 11a is then cut, for example by wire spark erosion, into the desired number of annular sectors (e.g. two, each of 180°).

[0037] Lastly, it is evident that the stator assembly described above can be subject to modifications and variations without departing from the scope of the present invention, as defined in the appended claims.

Claims

1. A stator assembly for a radial-axial expansion stage of a steam turbine, comprising:

   an anchoring ring (13) extending around an axis (A);
   a guide ring (15), extending around the axis (A);
   a plurality of tangential stator vanes (17), each having a respective airfoil (18) connected to respective portions of the anchoring ring (13) and of the guide ring (15), the stator vanes (17) being arranged around the axis (A) and configured to tangentially accelerate a steam flow entering from the outside toward the inside of the stator assembly;
   wherein the stator vanes (17) are formed in a single piece with the respective portions of the anchoring ring (13) and of the guide ring (15).

2. The stator assembly according to claim 1, comprising a plurality of annular sectors (20), each comprising a respective group of stator vanes (17), an anchoring ring sector (13a) and a guide ring sector (15a), wherein the stator vanes (17) of each annular sector (20) have the respective airfoil (18) connected to the respective anchoring ring sector (13a) and to the respective guide ring sector (15a).

3. The stator assembly according to claim 2, comprising two annular sectors (20), each extending over an arc of 180°, wherein each group of stator vanes (17) comprises half of the stator vanes (17) and

wherein the anchoring ring sectors (13a) and the guide ring sectors (15a) extend over arcs of 180°.

4. The stator assembly according to claim 2 or 3, wherein each annular sector (20) is formed in a single piece.

5. The stator assembly according to any one of claims 2 to 4, wherein each annular sector (20) comprises at least two respective stator vanes (17).

6. The stator assembly according to any one of the foregoing claims, wherein:

the anchoring ring (13), the guide ring (15) and the vanes define a substantially cylindrical region around the axis (A);
in each stator vane (17), the airfoil (18) has a leading edge (18a) and a trailing edge (18b) extending between the anchoring ring (13) and the guide ring (15); and
the airfoil (18) of each stator vane (17) has a concave side (18c) facing the outside of the cylindrical region and a convex side (18d) facing the inside of the cylindrical region.

7. A steam turbine comprising a radial-axial expansion stage provided with a stator assembly (11a) according to any one of the foregoing claims.

8. The steam turbine according to claim 7, comprising a shell (2) housing a rotor (3) rotatable about a rotation axis (A), the shell (2) being provided with an anchoring circumferential groove (21) and a guide circumferential groove (22); wherein the anchoring circumferential groove (21) and the guide circumferential groove (22) extend around the rotation axis (A) and house the anchoring ring (13) and the guide ring (15), respectively.

9. The steam turbine according to claim 8, wherein:

the anchoring circumferential groove (21) has a T-shaped cross-section and the anchoring ring (13) has a base (13b) and a connection portion (13c) projecting from the base (13b) towards the guide ring (15);
the base (13b) has edges projecting radially inwards and radially outwards with respect to the connection portion (13c), and wherein the anchoring ring (13) is radially and axially retained inside the anchoring circumferential groove (21).

10. A process for manufacturing a stator assembly of a radial-axial expansion stage of a steam turbine, comprising making:

an anchoring ring (13) extending around an axis (A);
a guide ring (15), extending around the axis (A);
a plurality of tangential stator vanes (17), each having a respective airfoil (18) connected to respective portions of the anchoring ring (13) and of the guide ring (15), the stator vanes (17) being arranged around the axis (A) and configured to tangentially accelerate a steam flow entering from the outside toward the inside of the stator assembly;
wherein the stator vanes (17) are formed in a single piece with the respective portions of the anchoring ring (13) and of the guide ring (15).

11. The process according to claim 10, comprising obtaining a semi-finished block and making the anchoring ring (13), the guide ring (15) and the plurality of stator vanes (17) by subtractive manufacturing from the semi-finished block.

12. The process according to claim 10 or 11, comprising cutting the anchoring ring (13) and the guide ring (15) to form a plurality of annular sectors (20), each comprising a respective group of stator vanes (17), a respective sector of the anchoring ring (13) and a respective sector of the guide ring (15).

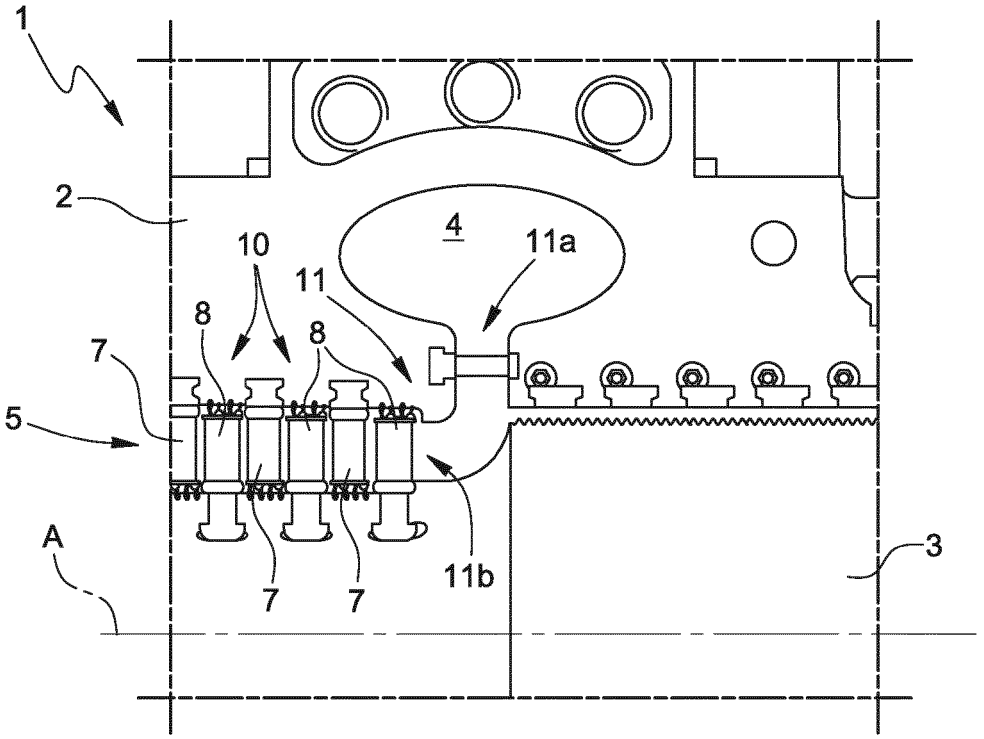

FIG. 1

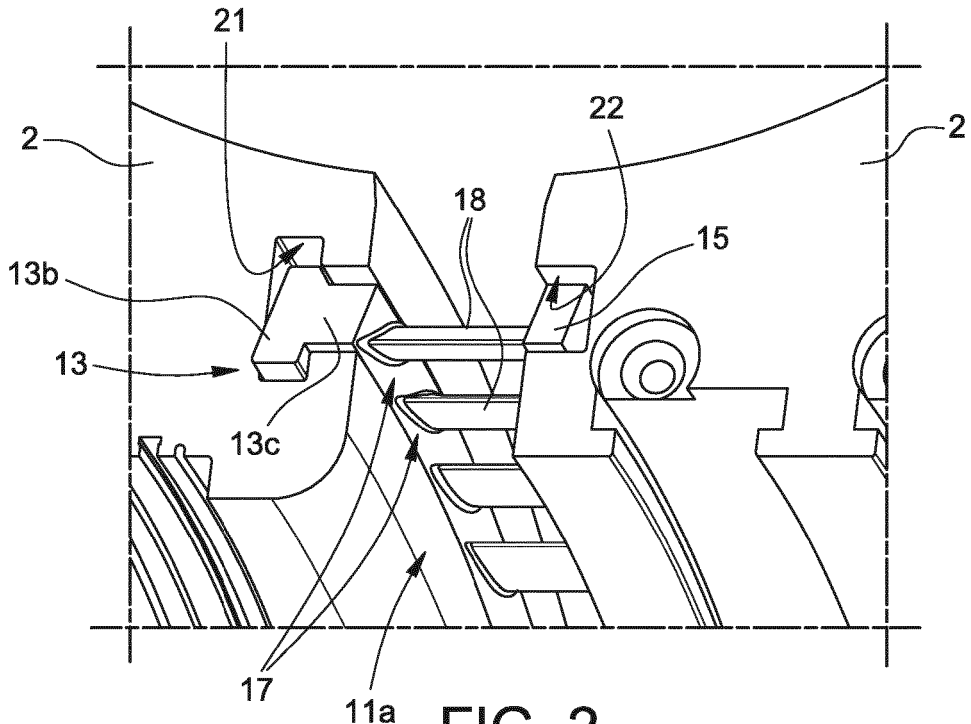

FIG. 2

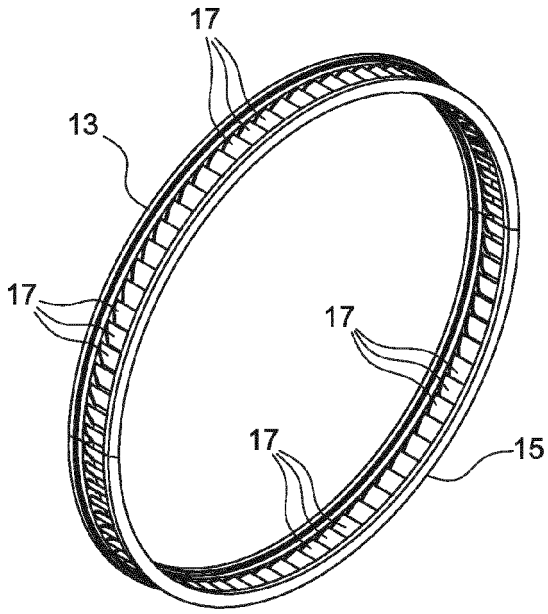

FIG. 3

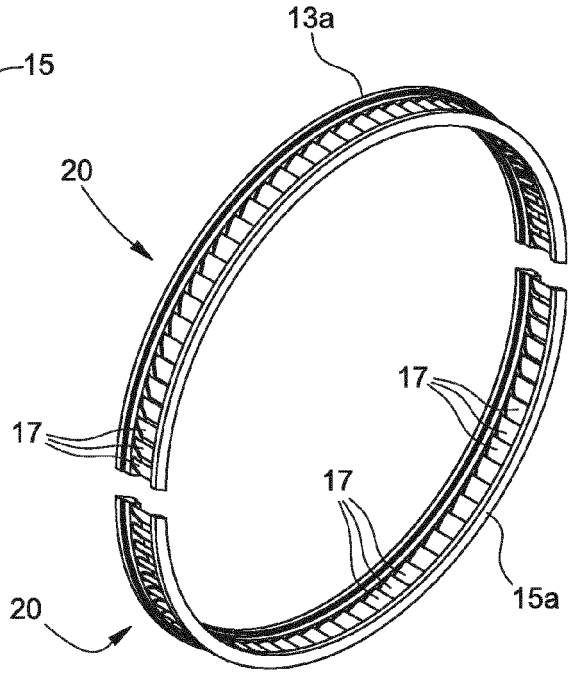

FIG. 4

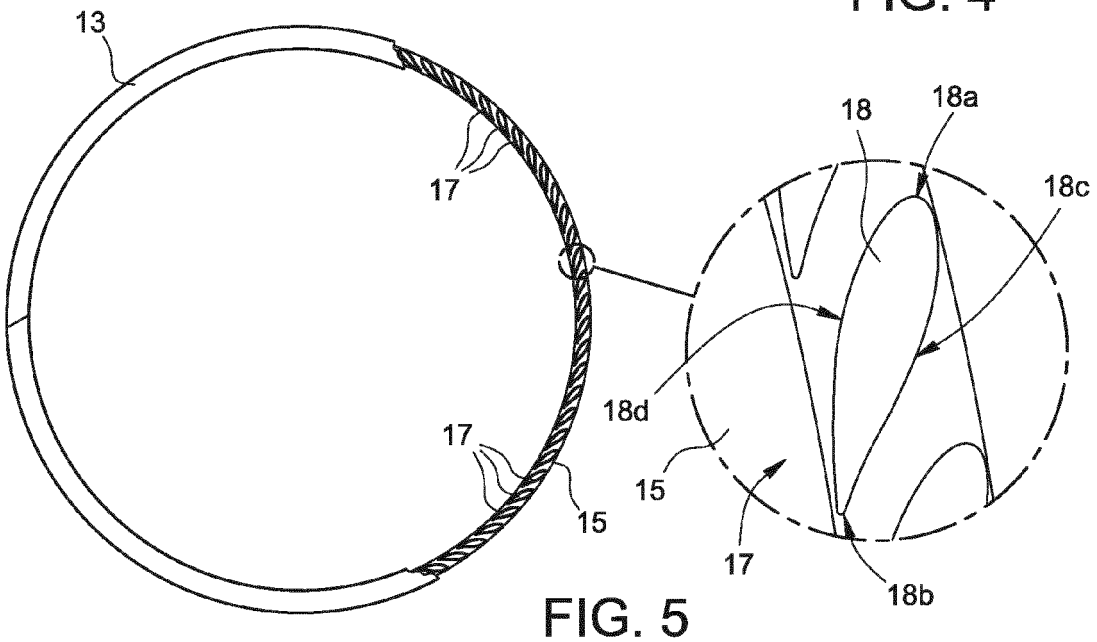

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	14 September 2018	Calabrese, Nunziante

CATEGORY OF CITED DOCUMENTS

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