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(54) **AXIAL TURBOMACHINE STATOR WITH SEGMENTED INNER SHELL**

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(57) **ABSTRACT**

The present application relates to a compressor stator of an axial turbomachine having an inner shell formed of a plurality of annular segments arranged end to end, a layer of abradable material applied on the inner face of the shell, and an annular array of blades connected to the shell. The stator has at least one strip located in the layer of abradable material and extending from either side of the junctions between two adjacent annular segments. The inner tips of the blades have hooks mating mechanically with the strip.

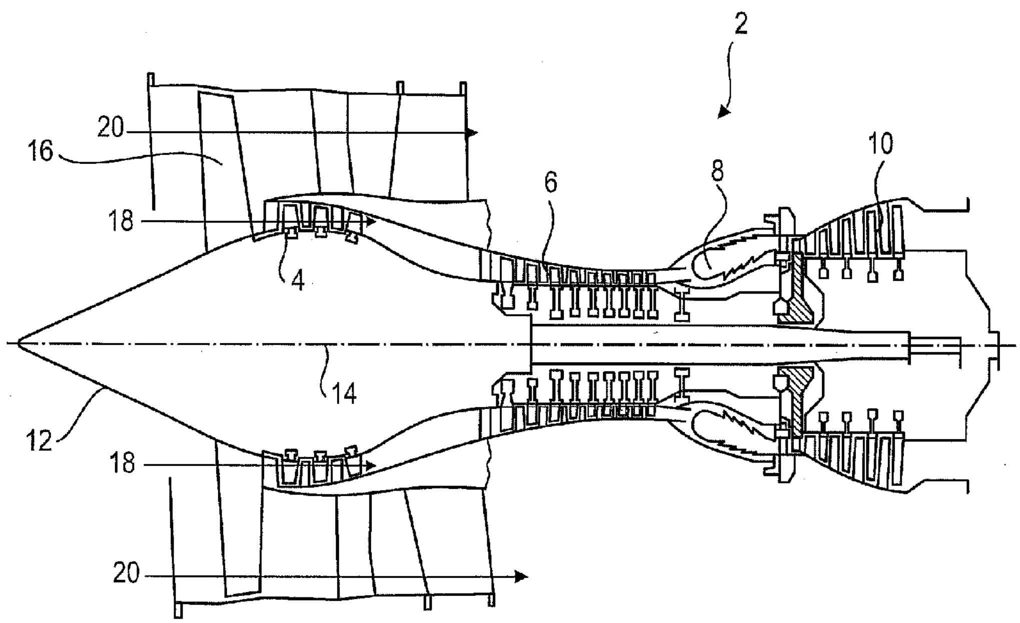

Fig. 1

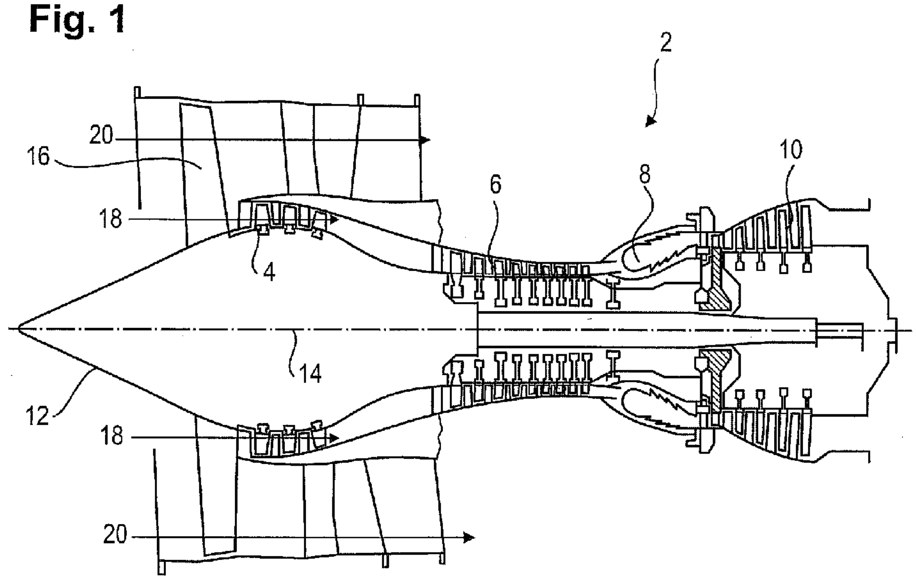
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Fig. 2

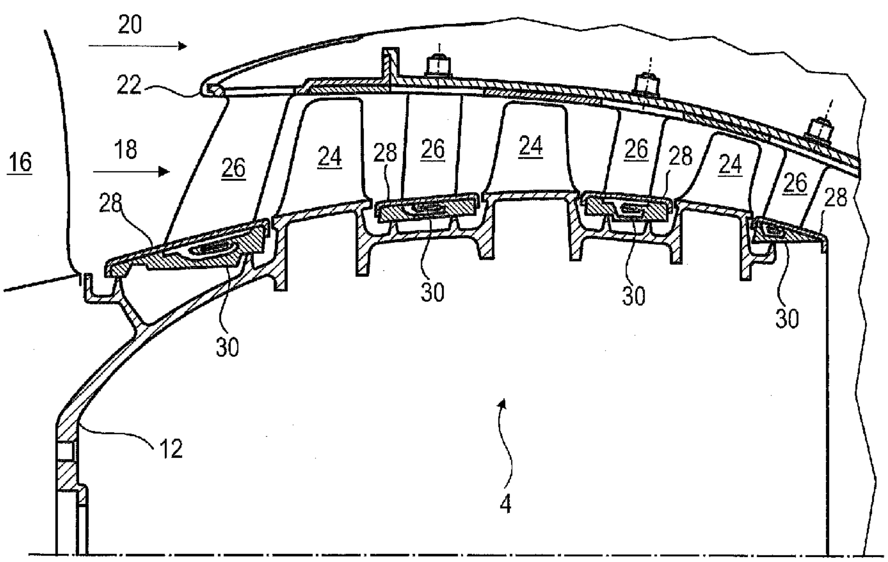
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Fig. 3

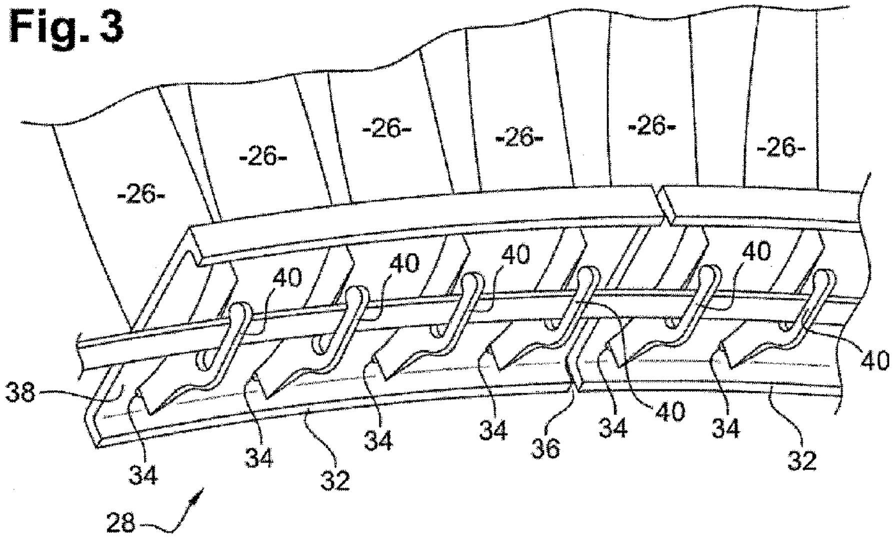
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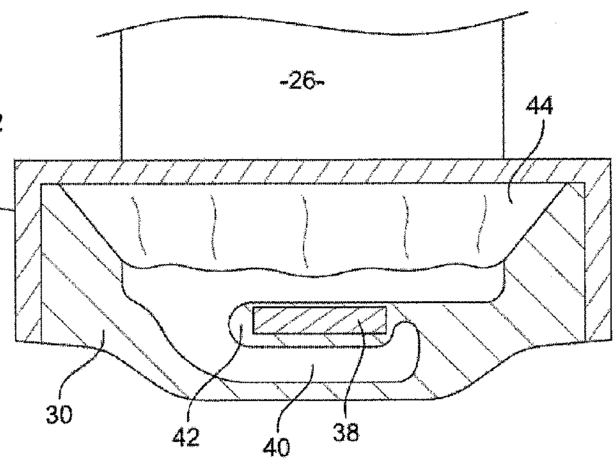
Fig. 4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AXIAL TURBOMACHINE STATOR WITH SEGMENTED INNER SHELL

[0001] This application claims priority under 35 U.S.C. §119 to European Patent Application No. 12194325.2, filed 27 Nov. 2012, which is incorporated herein by reference for all purposes.

BACKGROUND

[0002] 1. Field of the Application

[0003] The present application relates to an axial turbomachine. More particularly, the present application relates to a stator of an axial turbomachine comprising a segmented inner shell. The present application also relates to a stator assembly process. The present application also relates to an axial compressor.

[0004] 2. Description of Related Art

[0005] In order to guide an annular flow, an axial turbomachine is fitted with coaxial shells defining the inside and outside of the flow. In a stator, internal shells are essentially connected to the stator blade tips. They form cylindrical walls having openings through which the stator blade tips are inserted so as to fix them.

[0006] The openings are larger in order to facilitate inserting the blade tips, the gaps then having to be sealed.

[0007] To ensure a seal between the compressor stages, a layer of abradable material is deposited on each internal surface of the inner shells. These layers are intended to be flush with the tips of the radial fins which are formed on the rotor. The section of the inner shells may form a U so as to have an inner annular groove holding the layer of abradable material.

[0008] Patent EP 2196629 A1 discloses an inner ring of a bladed stator of a turbomachine. The shell has a U-shaped cross section in which the recess holds a layer of abradable material. The inner shell comprises a plurality of shell segments joined end to end. Their interfaces have surfaces designed to marry with the blades' aerodynamic surfaces. These segments have projections on one side and recesses on the other. The projections on one segment can mate with the recesses of an adjacent segment so that they can interlock.

[0009] Due to the relative flexibility of the abradable material and configuration of the projections, the segments are substantially movable relative to each other. However, in operation, such a shell is subjected to frequency excitations. As a consequence of this, the inner shell can develop destructive vibrational modes. In addition, the projections and recesses have a large radial thickness that affects the thickness of the segments. This need for an increased amount of material increases the weight of the shell and therefore affects its vibrational response.

[0010] Although great strides have been made in the area of stators for axial turbomachines, many shortcomings remain.

DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** shows an axial turbomachine in accordance with the present application.

[0012] FIG. **2** is a sectional view of the compressor of the turbomachine in FIG. **1** in accordance with the present application.

[0013] FIG. **3** illustrates two annular segments of a stator of the compressor in FIG. **1**, the stator being in accordance with the present application.

[0014] FIG. **4** is a sectional view of the shell of the stator shown in FIG. **3**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0015] The present application aims to solve at least one of the problems present in the prior art. More particularly, the present application aims to improve the vibrational behaviour of a stator with a segmented inner shell. The present application also aims to improve the construction of stators, particularly in terms of the connections between the blades and the inner shell.

[0016] The present application relates to a stator of an axial turbomachine compressor comprising an annular row of blades extending radially, an inner shell through which the inner tips of the blades pass, the said annular shell being formed of segments arranged end to end, wherein it further comprises at least one strip extending circumferentially along the inner surface of the shell and mating with an engaging member on the inner tips of the blades for their retention, the said strip(s) extending continuously along at least two adjacent annular segments.

[0017] According to an advantageous embodiment of the present application, the strip(s) is/are spaced from the inner surface of the shell, the said surface being preferably covered with a layer of abradable material embedding the strip(s).

[0018] According to an advantageous embodiment of the present application, the strip(s) extend(s) substantially parallel to the inner shroud.

[0019] According to an advantageous embodiment of the present application, the inner shell has an annular groove open to the interior which houses the layer of abradable material.

[0020] According to an advantageous embodiment of the present application, the layer of abradable material is continuous across the junctions between the segments.

[0021] According to an advantageous embodiment of the present application, the inner shell is made of metal or a composite material.

[0022] According to an advantageous embodiment of the present application, the or at least one of the strips has a flat section, the section preferably being solid.

[0023] According to one alternative of the present application, the or at least one of the strips has a circular section, possibly the, or at least one, strip is a wire or cable.

[0024] According to an advantageous embodiment of the present application, the strip or each of the strips extends over at least a quarter, preferably one third, more preferably one half, of each of two adjacent annular segments.

[0025] According to an advantageous embodiment of the present application, the strip(s) form(s) an open ring.

[0026] According to an advantageous embodiment of the present application, the means for engaging the inner tips of the blades comprise openings and/or hooks mating with the strip(s).

[0027] According to an advantageous embodiment of the present application, the means of engaging are remote from the upstream and downstream edges of the shell, the engaging member being preferably substantially central on the shell in an axial direction.

[0028] According to an advantageous embodiment of the present application, portions of the engaging member mating with the strip(s) have lengths in an axial direction which are greater than 100%, preferably 200%, of the width of the strip(s) so as to allow some variation in the positioning of the engaging member along the said direction.

[0029] According to an advantageous embodiment of the present application, the strip(s) has/have a profile matching that of the profile of the shell.

[0030] According to an advantageous embodiment of the present application, the profile(s) of the strip(s) between two adjacent blades correspond(s) to that of the shell.

[0031] According to an advantageous embodiment of the present application, the shell includes at least four annular segments, the strip or one of the strips spanning at least a twentieth, preferably at least an eighth, more preferably a quarter of the inner shell.

[0032] According to an advantageous embodiment of the present application, the strip is a metallic material, preferably titanium, steel or aluminium.

[0033] According to an advantageous embodiment of the present application, the engaging member for engaging the inner tips of the blades comprises hooks in which the throat is oriented in an axial direction.

[0034] According to an advantageous embodiment of the present application, the hooks have a lip in their throat, designed to restrain the strip(s) axially.

[0035] According to an advantageous embodiment of the present application, the hooks can be notches made laterally on the inner tips of the blades.

[0036] According to an advantageous embodiment of the present application, the stator comprises boundary seals at the junction between the openings and the blade tips, the beads of which extend radially inwardly from the inner surface of the inner shell, the strip(s) being spaced from the seals.

[0037] According to an advantageous embodiment of the present application, the width of the section of the strip(s) is greater than 10% of the width of the section of the inner shell, preferably greater than 20%, even more preferably greater than 30%.

[0038] According to an advantageous embodiment of the present application, the stator includes several strips whose ends overlap radially and possibly the ends are welded at the overlaps. Alternatively, the stator may comprise several strips the ends of which are spaced from each other.

[0039] According to yet another advantageous embodiment of the present application, the material of the strip(s) is substantially free of plastic deformations.

[0040] The present application also relates to a compressor, including that of an axial turbomachine, comprising at least one bladed stator wherein the or at least one stator is in accordance with the present application, the compressor preferably being a low-pressure compressor.

[0041] The device of the present application can modify the frequency response of the inner shell substantially by changing its stiffness at the joint between two segments. The strip remains flexible and does not form any stiffening completely blocking the junctions between segments. The choice to retain some flexibility is sufficient to contain the destructive vibrational modes of the inner shell.

[0042] The strip is essentially slender. It remains light, which does not change the mass or inertia of the shell affecting its frequency response when excited vibrationally. The device of the present application can act on the low-frequency vibrational modes that are most harmful. The choice of a slender and light strip is advisable since it is complementary to the abradable layer whose potential viscoelasticity can be exploited to dampen high frequency vibrations.

[0043] The device of the present application exploits the presence of the blades to improve the anchoring effects of the strip(s) at the same time as their own anchorages. In this way, the whole is more rigid and prevents low-frequency vibrational modes. Assembling the stator is thus facilitated by the present application.

[0044] As used herein, the terms 'inner' or 'internal' and 'outer' or 'external' refer to a position relative to the axis of rotation of an axial turbomachine.

[0045] FIG. **1** shows an axial turbomachine. In this case it is a double-flow turbojet. The turbojet **2** comprises a first compression stage, a so-called low-pressure compressor **4**, a second compression stage, a so-called high pressure compressor **6**, a combustion chamber **8** and one or more turbine stages **10**. In operation, the mechanical power of the turbine **10** is transmitted through the central shaft to the rotor **12** and drives the two compressors **4** and **6**. Reduction mechanisms may increase the speed of rotation transmitted to the compressors. Further, different turbine stages can be connected to the compressor stages through concentric shafts. Compressors comprise several rotor blade rows associated with stator blade rows. The rotation of the rotor thus generates a flow of air and progressively compresses it up to the inlet of the combustion chamber **10**.

[0046] An inlet fan, commonly designated a 'turbofan' **16**, is coupled to the rotor **12** and generates an airflow which is divided into a primary flow **18** passing through the various stages of the turbomachine mentioned above, and a secondary flow **20** passing through an annular conduit (shown in part) along the length of the machine and then rejoins the main flow at the turbine outlet. The primary flow **18** and secondary flow **20** are annular flows and are channelled through the housing of the turbomachine. To this end, the housing has cylindrical walls or shells that can be internal or external.

[0047] FIG. **2** is a sectional view of a low-pressure compressor **4** of an axial turbomachine **2** such as that of FIG. **1**. Part of the turbofan **18** can be seen, as can the splitter nose **22** between the primary **18** and secondary **20** airflows. The rotor **12** comprises several rows of rotor blades **24**, for example three.

[0048] The low-pressure compressor **4** includes several stators, for example four, each containing a row of stator blades **26**. Stators are associated with a fan **16** or a row of rotor blades for straightening the airflow so as to convert the velocity pressure of the stream into pressure.

[0049] The stator blades **26** extend substantially radially from an outer housing and can be fixed with a dowel. They are regularly spaced from each other, and have the same angular orientation to the stream. Advantageously, these blades are identical. Optionally, the spacing between the blades can vary locally as can their angular orientation. Some blades in a row can be different from the others.

[0050] The stators each comprise an inner shell **28** to guide the primary flow **18**. The shells **28** each have an annular row of openings. These are evenly distributed over the circumference of the internal shells and the inner tips of the blades pass through them in order to fix the shell. Internal shells **28** have a U-shaped cross section in which the hollow portion points inwards. Internal shells **28** may be made of metal, for example titanium alloy, or a composite material.

[0051] The stators each have an annular layer of abradable material **30** housed in the hollows of the internal shells **28**. The abradable layers **30** may be of substantially constant thickness, so as to form a band. These abradable layers **30** are intended to mate by abrasion with lip seals or circumferential fins so as to provide a seal. The layers of abradable material act as a filler and can be structural.

[0052] FIG. **3** shows a portion of the stator of the compressor of FIG. **2**. The inner shell **28** is essentially formed of a plurality of annular segments **32**. It is divided into annular sectors or annular segments, preferably regular. The annular segments **32** are arcuate. They each have a plurality of openings **34** in which the inner tips of the stator blades **26** are inserted. For example, each annular segment **32** can be linked to four blades **26**. However, it may be linked to more or less than four blades. The annular segments have the U-shaped section of the inner shell **28**, their hollow interior housing the annular layer of abradable material (not shown).

[0053] The annular segments **32** have gaps between them. They can be close together or some distance apart. However they are integral with each other because of the layer of abradable material. This layer creates a physical interface **36** between adjacent annular segments. Optionally, a blade tip may pass through an interface between the annular segments **32**.

[0054] The annular segments **32** are substantially rigid with respect to the layer of abradable material so that in the event of deformation or vibration of the inner shell **28**, any deformation is concentrated in that portion of the layer of abradable material located at the interface **36** between the annular segments **32**.

[0055] Depending on the operating conditions, the vibrations can be amplified so much so that the stator can experience critical mode vibrations that can become destructive. To control the impact of these critical modes, the stator is fitted with strips **38** passing through the interface **36** between the annular segments **32**. They are housed in the thickness of the layer of abradable material **30**.

[0056] Preferably, the same strip(s) pass(es) though several annular segments. Optionally, the stator comprises one strip passing along its entire circumference.

[0057] The strip(s) **38** comprise(s) a metallic material. An alloy of titanium or aluminium may be chosen to reduce the weight. A grade of steel can be used to reduce costs. The strip(s) **38** may be (an) extruded strip(s), for example of rectangular cross section. Such (a) strip(s) may have a thickness less than 0.50 mm, and a width of between 2.00 mm and 10.00 mm. The strip(s) can also be circular, possibly comprising a metal wire or cable.

[0058] The strips are solid. They are straight when manufactured. To be mounted in the stator, they are bent to follow the curvature of the inner shell. The materials of which they are made and their sections enable them to be sufficiently flexible to deform elastically when they are bent during assembly.

[0059] The inner tips of the blades **26** have an engaging member **40**. The engaging member may comprise openings and/or hooks **40**. They are hooked to the strip(s) **38** and also allow for radial retention of the blades **26** relative to the shell **28**, and optionally also locking the strip(s) axially. The hooks can be lateral notches formed on an upstream or downstream side of a blade, the notch having a substantially constant width.

[0060] FIG. **4** shows a cross section of the shell **28** of the stator of FIG. **3**. The hook **40** defines a cavity **42** axially elongated that can accommodate the strip **38**. The hook **40** has a throat **42** located axially in the cavity so as to allow insertion of the strip transversely to its elongation or axially along the stator's axis. The lip to the throat **42** may form a narrowing in the latter.

[0061] The throat **42** is generally adjusted in shape to the section of the strip, so that it has a shape similar to the section of the strip. Nevertheless, the size of the throat is greater than the section of the strip. This particularity enables it adjust to variations in the positioning of the blades, and in particular, their hooks **40**. The maximum variation in the axial positioning of the hook **40** can be more than 3.00 mm with respect to a nominal position. The maximum variation in the radial positioning of a hook **40** can be greater than 2.00 mm relative to a nominal position.

[0062] One of the hooks **40** need not be in contact with a strip. One of the hooks **40** may be in contact with a strip substantially axially or radially.

[0063] The strip(s) **38** is/are positioned in the depth of the layer of abradable material **30**. It is/They are positioned in the heart of the abradable layer, allowing it/them to be enclosed on all sides. It/They form(s) a core in the layer of abradable material and change(s) its behaviour. Thus, it/they can change the elasticity of the physical junction which is formed by the layer of abradable material **30**.

[0064] The mass of the strip(s) is/are negligible compared to that of the combined mass of the shell and the abradable. This mass is less than 5% of the combined mass of the shell and the abradable, preferably less than 1%. Thus, the addition of the strip(s) does not significantly alter the mass of the whole, and does not introduce any new critical mode frequencies. If the mass had been increased new critical mode frequencies below those already in existence may occur. These new modes and their harmonics increase the risk of damage.

[0065] A silicone seal **44** is formed at the junction between the blades **26** and the openings. It improves sealing and temporarily holds the annular segment **32** against the blades **26** during assembly. It forms a bead which is made before inserting the strip(s) **38**. Advantageously, the inner side of the silicone seal **44** is spaced away from the strip(s) **38**. This feature improves the embedding of the strip(s) in the abradable material.

[0066] The overall configuration is particularly advantageous since it allows easy assembly of the stator. Such an assembly method is based on the following steps:

[0067] assemble, or use a pre-assembled, annular array of blades fitted on an exterior medium, an inner shell being fitted to the inner tips of the blades;

[0068] insert a strip at the inner tips of the blades, the strip being positioned on the axial side of the hook throats. Its ends are each in contact with an inner blade tip, and its central part is at some distance from the blades;

[0069] bend the middle of the strip **38** so that it comes into contact with the inner tips of the blades along its entire length—the strip is thus curved so as to be parallel with the line of the hook throats;

[0070] slide the strip axially into the hooks and then release it; and

[0071] fit the layer of abradable material into the inner shell.

[0072] It is worth stressing that steps b), c) and d) can be done in a few seconds for a strip in contact with a dozen blades. The installation time is reduced and reduces the cost of labor.

1. A stator of a compressor of an axial turbomachine, comprising:

an annular ring of blades extending radially;

an inner shell through which the inner tips of the blades pass, the shell comprising annular segments arranged end to end; and

at least one strip extending circumferentially along the length of the inner surface of the shell and mating with an engaging member for engaging the inner tips of the blades for retention thereof, each strip extending continuously along at least two adjacent annular segments.

2. The stator in accordance with claim **1**, wherein each strip is spaced from the inner surface of the shell, the surface being covered with a layer of abradable material embedding each strip.

3. The stator in accordance with claim **1**, wherein at least one of the strips has a flat solid section.

4. The stator in accordance with claim **1**, wherein each of the strips extends over at least a quarter of each of two adjacent annular segments.

5. The stator in accordance with claim **1**, wherein each of the strips extends over at least a third of each of two adjacent annular segments.

6. The stator in accordance with claim **1**, wherein each of the strips extends over at least a half of each of two adjacent annular segments.

7. The stator in accordance with claim **1**, wherein the strip forms an open ring.

8. The stator in accordance with claim **1**, wherein the engaging member of the inner tips of the blades comprises:

openings mating with the strips.

9. The stator in accordance with claim **1**, wherein the engaging member of the inner tips of the blades comprises:

hooks mating with the strips.

10. The stator in accordance with claim **1**, wherein the engaging member is spaced upstream and downstream of the shell, being essentially central in the shell in an axial direction.

11. The stator in accordance with claim **1**, wherein the portions of the engaging member mating with the strips has lengths in an axial direction which are more than 100% the width of the strips, so as to allow a variation of positioning of engaging member along the said direction.

12. The stator in accordance with claim **1**, wherein the portions of the engaging member mating with the strips has lengths in an axial direction which are more than 200% the width of the strips, so as to allow a variation of positioning of engaging member along the said direction.

13. The stator in accordance with claim **1**, wherein the strips have an annular profile matching that of the profile of the shell.

14. The stator in accordance with claim **13**, wherein the profile of the strips between two adjacent blades matches that of the shell.

15. The stator in accordance with claim **1**, wherein the shell comprises:

at least four annular segments;

wherein the strips span at least a quarter of the inner shell.

16. The stator in accordance with claim **1**, wherein the shell comprises:

at least four annular segments;

wherein the strips span the entire inner shell.

17. The stator in accordance with claim **1**, wherein the strips are made of a metallic material chosen from the group:

titanium;

steel; or

aluminium.

18. The stator in accordance with claim **1**, wherein the engaging member comprises:

hooks whose throats are oriented in an axial direction.

19. The stator in accordance with claim **18**, wherein the hooks have lips at the throats thereof for restraining the strips axially.

20. A compressor of an axial turbomachine, comprising:

a low pressure compressor;

an annular ring of blades extending radially;

an inner shell through which the inner tips of the blades pass, the shell comprising annular segments arranged end to end; and

at least one strip extending circumferentially along the length of the inner surface of the shell and mating with a engaging member the inner tips of the blades for their retention, each strip extending continuously along at least two adjacent annular segments.

* * * * *