(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 322 832 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
25.08.2021 Bulletin 2021/34

(21) Application number: **16736885.1**

(22) Date of filing: **11.07.2016**

(51) Int Cl.:
C23C 4/18 *(2006.01)* ***B05B 13/04*** *(2006.01)*
C23C 24/04 *(2006.01)* ***C23C 24/10*** *(2006.01)*
C23C 4/01 *(2016.01)* ***C23C 4/08*** *(2016.01)*

(86) International application number:
PCT/EP2016/066445

(87) International publication number:
WO 2017/009295 (19.01.2017 Gazette 2017/03)

(54) METHOD OF FORMING A PROTECTIVE STRUCTURE ON A TURBOMACHINE BLADE

VERFAHREN ZUR FORMUNG EINER SCHUTZSTRUKTUR AUF EINER TURBOMASCHINENSCHAUFEL

PROCÉDÉ DE FORMATION D'UNE STRUCTURE DE PROTECTION SUR UNE AUBE DE TURBOMACHINE

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **13.07.2015 IT UB20152136**

(43) Date of publication of application:
23.05.2018 Bulletin 2018/21

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Description

TECHNICAL FIELD

[0001] Embodiments of the subject matter disclosed herein correspond to turbomachine blades with protective structure, turbomachines (in particular steam turbines), and methods of forming protective structure.

BACKGROUND ART

[0002] WO 2008/116757 A2 discloses a compressor blade with a first layer provided on the surface of the blade body in a leading edge area and a second layer that covers the first layer and the remaining non-covered parts of the blade body surface. US 2013/236323 A1 discloses a leading edge protection component, US 2014/272166 A1 discloses an airfoil coating, EP 2 631 323 A1 discloses a coating for an airfoil blade component and US 2011/097213 A1 discloses leading edge protection.

[0003] During operation, the blades of turbomachines are often subject to erosion.

[0004] In particular, the blades of steam turbines are often subject to liquid droplet erosion. Structures for protecting turbomachine blades against erosion, corrosion or wear may consist of layers formed on the surface of the blades or inserts fit in the body of the blades.

[0005] Protective layers may be formed for example by laser cladding or by cold spraying. Both these technologies are effective. Anyway, laser cladding heats the blades and may cause for example residual stress in the blades and/or distortion of the blades and may foster "stress corrosion cracking", while cold spraying hits the blades and may cause for example erosion of the edges of the blades during formation of the layers. It is to be noted that laser cladding is more expensive than cold spraying, but is quicker.

SUMMARY

[0006] Therefore, there is a general need for improving the protective structures of turbomachine blades and the methods of forming them.

[0007] This need is particularly high for blades of steam turbines in the fields of "Oil & Gas" (i.e. machines and plants for exploration, production, storage, refinement and distribution of oil and/or gas) and "Energy" (i.e. machines and plants for power generation).

[0008] First embodiments of the subject matter disclosed herein relate to a turbomachine blade.

[0009] According to such embodiments, the turbomachine blade is provided with an airfoil portion having a leading edge and a trailing edge and first and second sides connecting the leading edge and the trailing edge, and with a protective structure comprising a protective edging and first and second protective stripes; the protective edging is located on the leading edge; the first protective stripe is located on the first side and adjacent to the edging; the second protective stripe is located on the second side and adjacent to the edging; the edging is formed by laser cladding or welding or plasma spraying or detonation spraying or wire arc spraying or flame spraying or high velocity oxyfuel coating spraying or warm spraying; the first and second stripes are formed by cold spraying.

[0010] Second embodiments of the subject matter disclosed herein relate to a turbomachine.

[0011] According to such embodiments, a turbomachine, in particular a steam turbine, comprises a plurality of turbomachine blades as set out above.

[0012] Third embodiments of the subject matter disclosed herein relate to a method of forming protective structure.

[0013] According to such embodiments, a method of forming a protective structure on a turbomachine blade comprises the following successive steps: (A) providing a turbomachine blade comprising an airfoil portion having a leading edge and a trailing edge and first and second sides connecting the leading edge and the trailing edge, (B) forming a protective edging on the leading edge by laser cladding, and (C) forming first and second protective stripes on the first and second sides adjacently to the edging by cold spraying through at least one spraying nozzle. The current invention is limited to the subject-matter of claim 1 and the appended claims.

BRIEF DESCRIPTION OF DRAWINGS

[0014] The accompanying drawings, which are incorporated herein and constitute an integral part of the present specification, illustrate exemplary embodiments and, together with the detailed description, explain these embodiments. In the drawings:

Fig. 1 shows a schematic lateral view of an embodiment of a turbomachine blade before forming a protective structure;

Fig. 2 shows a schematic lateral view of an embodiment of a turbomachine blade during formation of a protective structure;

Fig. 3 shows a schematic lateral view of an embodiment of a turbomachine blade after forming a protective structure;

Fig. 4 shows schematically a detail of Fig. 3;

Fig. 5 shows schematically a cross-section view of Fig. 4;

Fig. 6 shows a schematic and partial cross-section view of an embodiment of a turbomachine blade before forming a protective structure;

Fig. 7 shows a schematic and partial cross-section view of an embodiment of a turbomachine blade during formation of a protective structure (first intermediate stage);

Fig. 8 shows a schematic and partial cross-section view of an embodiment of a turbomachine blade dur-

ing formation of a protective structure (second intermediate stage);

Fig. 9 shows a schematic and partial cross-section view of an embodiment of a turbomachine blade after forming a protective structure;

Fig. 10 shows a schematic lateral view of an embodiment of a turbomachine blade after forming a protective structure in a way alternative to one of Fig. 3;

Fig. 11 shows first possible schematic and partial cross-section view of an embodiment of a turbomachine blade after forming a protective structure;

Fig. 12 shows second possible schematic and partial cross-section view of an embodiment of a turbomachine blade after forming a protective structure;

Fig. 13 shows third possible schematic and partial cross-section view of an embodiment of a turbomachine blade after forming a protective structure; and

Fig. 14 shows fourth possible schematic and partial cross-section view of an embodiment of a turbomachine blade after forming a protective structure.

DETAILED DESCRIPTION

[0015] The following description of exemplary embodiments refers to the accompanying drawings.

[0016] The following description does not limit the invention. Instead, the scope of the invention is defined by the appended claims.

[0017] Reference throughout the specification to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with an embodiment is included in at least one embodiment of the subject matter disclosed. Thus, the appearance of the phrases "in one embodiment" or "in an embodiment" in various places throughout the specification is not necessarily referring to the same embodiment. Further, the particular features, structures or characteristics may be combined in any suitable manner in one or more embodiments.

[0018] Fig. 1 shows a schematic lateral view of a turbomachine blade 1 before forming a protective structure. Blade 1 is provided with an airfoil portion 2 having a leading edge 3 and a trailing edge 4 as well as a first side 5 and a second side 6 (shown only in Fig. 5) connecting leading edge 3 and the trailing edge 4. Airfoil portion 2 has a tip region 21 and a base region 22; base region 22 of airfoil portion 2 is adjacent to base portion 10 of blade 1.

[0019] Fig. 3, Fig. 4 and Fig. 5 show blade 1 after forming a protective structure. The protective structure comprises a protective edging 7 (that may be called "bumper" or "buffer") as well as a first protective stripe 8 and a second protective stripe 9 (shown only in Fig. 5); protective edging 7 is located on leading edge 3; first protective stripe 8 is located on first side 5 and adjacent to edging 7; second protective stripe 9 is located, preferably only, on second side 6 and adjacent to edging 7.

[0020] In the embodiment of Fig. 5, stripes 8 and 9 do not cover edging 7 and are located respectively only on sides 5 and 6.

[0021] In the embodiment of Fig. 9, stripes 8 and 9 are located respectively on sides 5 and 6, but cover also entirely edging 7; the thickness of stripes 8 and 9 reduces gradually on edging 7 and is zero (or close to zero) in the middle of edging 7.

[0022] In the embodiment of Fig. 11 (similar to Fig. 5), the two stripes do not cover edging 171 and are located respectively only on the two sides of the airfoil.

[0023] In the embodiment of Fig. 12 (similar to Fig. 9), the two stripes are located respectively on the two sides of the airfoil, but cover also partially edging 172; the thickness of the stripes reduces gradually on the edging and is zero (or close to zero) in the middle of the edging.

[0024] In the embodiment of Fig. 13, the two stripes are located respectively on the two sides of the airfoil, but cover also entirely edging 173; the thickness of the stripes reduces gradually on the edging and is minimum and low in the middle of the edging.

[0025] In the embodiment of Fig. 14, the two stripes are located respectively on the two sides of the airfoil, but cover also entirely edging 173; the thickness of the stripes reduces gradually on the edging and is minimum and high in the middle of the edging.

[0026] According to these embodiments, the edging of the protective structure protrudes from the leading edge of the airfoil portion of the blade. Protrusion (at the end of blade manufacturing) varies depending on the manufacturing process (e.g. degree of erosion due to cold spraying). Considering the camber line (100 in figures 11-14) of the airfoil portion and its prolongation, protrusion may be in the range of e.g. from 0.05 to 1 mm.

[0027] The cross-section area of the edging (immediately after its formation, e.g. before cold spraying) should take into account the manufacturing process (e.g. degree of erosion due to cold spraying) and may be in the range from 1 mm^2 to 20 mm^2, more typically in the range from 4 mm^2 to 10 mm^2. The cross-section area of the edging (immediately after its formation, e.g. before cold spraying) should take into account the manufacturing process (e.g. degree of erosion due to cold spraying) and may look like a bulge.

[0028] The external shape of the airfoil portion of the blade at the end of blade manufacturing depends on the external shape of the airfoil portion of the blade before formation of the protective structure and on the overlying protective structure, in particular the protective edging and its erosion during formation of the protective stripes. Therefore, at least the leading edge of the airfoil portion of the blade before formation of the protective structure should be manufactured a bit recessed with respect to the ideal position of the leading edge of the airfoil portion of the blade at the end of blade manufacturing.

[0029] The solution according to the above embodiments is particular useful for thin blades, for example blades having a thin leading edge, for example in the range of 4-8 mm.

[0030] As it will be explained better afterward, the edg-

ing of the protective structure is formed by laser cladding or welding or plasma spraying or detonation spraying or wire arc spraying or flame spraying or high velocity oxyfucl coating spraying or warm spraying (preferably by laser cladding), while the first and second stripes of the protective structure are formed by cold spraying.

[0031] The airfoil portion of the blade may be made of iron, titanium, nickel base alloy or stainless steel; preferably, it is made of stainless steel, for example AISI420.

[0032] The edging of the protective structure may be made of cobalt base alloy or cobalt-chromium alloy; preferably, it is made of Stellite-type material, in particular Stellite 6 or Stellite 12 or Stellite 21, or Ultimet or any of the materials described and claimed in patent application EP1403397 or any of the materials described and claimed in patent application EP1403398. The material of the edging is more resistant to solid particle erosion than the material of the airfoil in order to resist better to the mechanical erosion due to cold spraying.

[0033] The first and second stripes of the protective structure may be made of cobalt base alloy or cobalt-chromium alloy; preferably, they are made of Stellite-type material, in particular Stellite 6 or Stellite 12 or Stellite 21, or Ultimet or any of the materials described and claimed in patent application EP1403397 or any of the materials described and claimed in patent application EP1403398. The material of the first and second stripes is resistant to liquid droplet erosion. The material of the first and second stripes may be equal to or different from the material of the edging.

[0034] The edging of the protective structure and the first and second stripes of the protective structure may extend over part (i.e. from preferably 20% to preferably 50%) of the height of the airfoil portion of the blade (see e.g. Fig. 3 and Fig. 10). Typically, the head end of the stripes is at the tip of the airfoil portion and the tail end of stripes is at an intermediate position of the airfoil portion. Preferably the edging of the protective structure is long equal to or slightly more than the first and second stripes of the protective structure. The height of the airfoil portion being the portion of the blade extending from the tip to the root of the blade.

[0035] The first and second stripes of the protective structure may extend over part (i.e. from preferably 5% to preferably 50%) of the width of the airfoil portion of the blade (see e.g. Fig. 3 and Fig. 10). Typically, the stripes extend from leading edge of the airfoil portion of the blade. The width of the airfoil portion being the portion of the blade extending from the leading to the trailing edge.

[0036] Blades identical or similar to those that have just been described may advantageously be used in turbomachines in the fields of "Oil & Gas" and "Energy". In particular, thanks to their resistance to liquid droplet erosion, steam turbines are an ideal application.

[0037] A protective structure identical or similar to those that have just been described (see Fig. 3+4 and Fig. 10) may be formed on a turbomachine blade through the following successive steps:

A) providing a turbomachine blade comprising an airfoil portion having a leading edge and a trailing edge and first and second sides connecting the leading edge and the trailing edge, (see e.g. Fig. 1 and Fig. 6)

B) forming a protective edging on the leading edge by laser cladding, (see e.g. Fig. 2 and Fig. 7)
and

C) forming first and second protective stripes on the first and second sides adjacently to the edging by cold spraying through at least one spraying nozzle, which is a very effective way of forming thin and well adhering layers of materials resistant to erosion. (see e.g. Fig. 3 and Fig. 5 or Fig. 9)

[0038] In this way, the leading edge of the airfoil is protected by the edging and the cross-section of the airfoil is well covered through cold spraying both laterally and frontally.

[0039] This is particularly advantageous for thin blades, more in particular for blades having a thin leading edge; a "thin leading edge" may have a thickness in the range of e.g. 2-10 mm - as the cross-section of the leading edge is similar to a semicircle, a "thin leading edge" may have a radius in the range of e.g. 1-5 mm. In this way, heating of the blades due to laser cladding is quite low and therefore residual stress in the blades and distortion of the blades and "stress corrosion cracking" in the blades are quite low.

[0040] The same spraying nozzle may be used for forming both protective stripes. Alternatively, a first spraying nozzle may be used for forming a first protective stripe and a second spraying nozzle may be used for forming a second protective stripe; in this case, the first and second protective nozzles may be formed at the same time.

[0041] The stripes of the protective structure may comprise a plurality of parallel (or substantially parallel) segments. In figures 4-9, segments 81 and 91 are transversal (specifically perpendicular) to the leading edge 3. In figures 10-14, segments 181 are parallel (or substantially parallel) to the leading edge 103. It is to be noted that these segments touch each other laterally even if Fig. 4 and Fig. 10 show them as distant.

[0042] According to the invention of claim 1, the spraying nozzle moves at least from a side (e.g. 5 or 6) of the airfoil portion toward the edging (e.g. 7) for forming a stripe (e.g. 8 or 9) and rotates preferably by at least 40° about the leading edge (e.g. 3) in order to form a stripe (e.g. 8 or 9) adjacent to the leading edge (e.g. 3) and to the edging (e.g. 7). During the initial part of the motion of the spraying nozzle, the spraying jet is directed highly inclined (preferably perpendicular) to the surface of (the side of) the airfoil; when the spraying nozzle approaches the leading edge the spraying nozzle is gradually rotated so that the spraying jet remains directed highly inclined (preferably perpendicular) to the surface of (the front of) the airfoil.

[0043] As a first alternative, step C may comprise (consider e.g. figures 6-9):

- a first sub-step C1A (see Fig. 8) wherein a spraying nozzle moves from a first side (e.g. 5) of the airfoil portion toward the edging (e.g. 70, 71, 72) and rotates by at least 40° and preferably 80-90° thus forming a segment (e.g. 81) of a first stripe (e.g. 8),
  and immediately after

- a second sub-step C2A (see Fig. 9) wherein a spraying nozzle moves from a second side (e.g. 6) of the airfoil portion toward the edging (e.g. 70, 71, 72) and rotates by at least 40° and preferably 80-90° thus forming a segment (e.g. 91) of a second stripe (9);

preferably, during sub-steps C1A and C2A the spraying nozzle maintains a constant longitudinal position on the airfoil portion.

[0044] In this way, two separate segments are formed at the same level on the two sides of the airfoil portion.

[0045] If sub-steps C1A and C2A are repeated at different levels several times two stripes are formed on the two sides of the airfoil portion, contemporaneously.

[0046] As a second alternative, step C may comprise:

- a first sub-step C1B wherein a spraying nozzle moves from a first side (e.g. 5) of the airfoil portion toward the edging (e.g. 70, 71, 72) and rotates by at least 40° and preferably 80-90° thus forming a segment (e.g. 81) of a first stripe (e.g. 8),
  and immediately after

- a second sub-step C2B (see Fig. 9) wherein the same spraying nozzle rotates by at least 40° and preferably 80-90°, and moves away from the edging (e.g. 7) to the first side (e.g. 5) of the airfoil portion thus forming another segment (e.g. 81) of the same first stripe (e.g. 8);

preferably, during sub-steps C1B and C2B the spraying nozzle maintains a constant longitudinal position on the airfoil portion, and the spraying nozzle is slightly displaced longitudinally after sub-step C1B and before sub-step C2B.

[0047] In this way, two parallel segments are formed at different levels on the same side of the airfoil portion in two manufacturing operations.

[0048] If sub-steps C1B and C2B are repeated several times one stripe is formed on one side of the airfoil portion. Afterwards, another stripe is formed on the other side of the airfoil portion.

[0049] As a third alternative, step C may comprise:

- a first sub-step C3 wherein a spraying nozzle moves from the first side (e.g. 5) of the airfoil portion toward the edging (e.g. 7) thus forming a segment (e.g. 81) of the first stripe (e.g. 8),

- a second sub-step C4 wherein the same spraying nozzle rotates about the leading edge (e.g. 3) by 80-180° thus forming a (typically thin) connecting segment,

- a third sub-step C5 wherein the same spraying nozzle moves away from the edging (e.g. 7) to the second side (e.g. 6) of the airfoil portion thus forming a segment (e.g. 91) of the second stripe (e.g. 9);

preferably, during sub-steps C3, C4 and C5 the spraying nozzle maintains a constant longitudinal position on the airfoil portion.

[0050] In this way, two consecutive segments are formed at the same level on the two sides of the airfoil portion.

[0051] If sub-steps C3, C4 and C5 are repeated at different levels several times two stripes are formed on the two sides of the airfoil portion, contemporaneously.

[0052] According to the third alternative, step C may comprise also the following sub-steps after sub-step C5:

- a fourth sub-step C6 wherein the same spraying nozzle moves from the second side (e.g. 6) of the airfoil portion toward the edging (e.g. 7) thus forming a segment of the second stripe (e.g. 9) adjacent to the previous one,

- a fifth sub-step C7 wherein the same spraying nozzle rotates about the leading edge (e.g. 3) by 80-180° thus forming a (typically thin) connecting segment,

- a sixth sub-step C8 wherein the same spraying nozzle moves away from the edging (e.g. 7) to the first side (e.g. 5) of the airfoil portion thus forming a segment of the first stripe adjacent (e.g. 8) to the previous one;

the spraying nozzle being slightly displaced longitudinally after sub-step C5 and before sub-step C6.

[0053] Preferably, during sub-steps C6, C7 and C8 the spraying nozzle maintains a constant longitudinal position on the airfoil portion.

[0054] In this way, further two segments (adjacent to the first two segments) are formed at the same level on the two sides of the airfoil portion.

[0055] If sub-steps C3, C4, C5, C6, C7 and C8 are repeated at different levels several times two stripes are formed on the two sides of the airfoil portion, contemporaneously.

Claims

1. A method of forming a protective structure on a turbomachine blade (1), wherein, the method comprises the following successive steps:

A) providing a turbomachine blade (1) comprising an airfoil portion (2) having a leading edge (3) and a trailing edge (4) and first and second sides (5, 6) connecting the leading edge (3) and the trailing edge (4),
B) forming a protective edging (7) on the leading edge (3) by laser cladding, and
C) forming first and second protective stripes (8, 9) on the first and second sides (5, 6) adjacently to the edging by cold spraying through a spraying nozzle;

wherein the spraying nozzle moves at least from a side (5,6) of the airfoil portion (2) toward the edging (7) for forming a stripe (8,9) and rotates about the leading edge (3) in order to form the stripe (8,9) adjacent to the leading edge (3) and to the edging (7).

2. The method of claim 1, wherein the first protective stripe (8) is formed before or after or contemporaneously with the second protective stripes (9).

3. The method of claim 1 or claim 2, wherein the stripes (8, 9) comprise a plurality of parallel segments (81, 91) transversal to the leading edge (3).

4. The method of any preceding claim, wherein, in step C, the spraying nozzle moves from a side (5, 6) of the airfoil portion toward the edging (7) and rotates by at least 40°, preferably 80-90°.

5. The method of any preceding claim, wherein step C comprises:

a first sub-step C3 wherein the spraying nozzle moves from the first side (5) of the airfoil portion (2) toward the edging (7) thus forming a segment (81) of the first stripe (8),
a second sub-step C4 wherein the spraying nozzle rotates about the leading edge (3) by 80-180° thus forming a connecting segment,
a third sub-step C5 wherein the spraying nozzle moves away from the edging (7) to the second side (6) of the airfoil portion (2) thus forming a segment (91) of the second stripe (9).

6. The method of claim 5, wherein step C comprises the following sub-steps after sub-step C5:

a fourth sub-step C6 wherein the spraying nozzle moves from the second side of the airfoil portion toward the edging thus forming a segment of the second stripe adjacent to the previous one,
a fifth sub-step C7 wherein the spraying nozzle rotates about the leading edge by 80-180° thus forming a connecting segment,
a sixth sub-step C8 wherein the spraying nozzle moves away from the edging to the first side of the airfoil portion thus forming a segment of the first stripe adjacent to the previous one;
wherein the spraying nozzle is displaced longitudinally after sub-step C5 and before sub-step C6.

7. The method of any preceding claim, wherein the stripes (108) comprise a plurality of parallel segments (181) parallel to the leading edge (103).

Patentansprüche

1. Verfahren zur Formung einer Schutzstruktur auf einer Turbomaschinenschaufel (1), wobei das Verfahren die folgenden aufeinanderfolgenden Schritte umfasst:

A) Bereitstellen einer Turbomaschinenschaufel (1), umfassend einen Schaufelblattabschnitt (2) mit einer Vorderkante (3) und einer Hinterkante (4) und einer ersten und einer zweiten Seite (5, 6), die die Vorderkante (3) und die Hinterkante (4) verbinden,
B) Formen einer Schutzumrandung (7) an der Vorderkante (3) durch Laserplattieren, und
C) Formen eines ersten und eines zweiten Schutzstreifens (8, 9) auf der ersten und der zweiten Seite (5, 6) angrenzend an die Umrandung durch Kaltspritzen durch eine Spritzdüse; wobei sich die Spritzdüse mindestens von einer Seite (5, 6) des Schaufelblattabschnitts (2) in Richtung der Umrandung (7) bewegt, um einen Streifen (8, 9) zu formen, und sich um die Vorderkante (3) dreht, um den Streifen (8, 9) angrenzend an die Vorderkante (3) und an die Umrandung (7) zu formen.

2. Verfahren nach Anspruch 1, wobei der erste Schutzstreifen (8) vor oder nach oder gleichzeitig mit den zweiten Schutzstreifen (9) geformt wird.

3. Verfahren nach Anspruch 1 oder Anspruch 2, wobei die Streifen (8, 9) mehrere parallele Segmente (81, 91) quer zur Vorderkante (3) umfassen.

4. Verfahren nach einem der vorstehenden Ansprüche, wobei sich in Schritt C die Spritzdüse von einer Seite (5, 6) des Schaufelblattabschnitts in Richtung der Umrandung (7) bewegt und sich um mindestens 40°, vorzugsweise 80 - 90° dreht.

5. Verfahren nach einem der vorstehenden Ansprüche, wobei der Schritt C umfasst:

einen ersten Unterschritt C3, wobei sich die Spritzdüse von der ersten Seite (5) des Schau-

felblattabschnitts (2) in Richtung der Umrandung (7) bewegt, wodurch ein Segment (81) des ersten Streifens (8) geformt wird,
einen zweiten Unterschritt C4, wobei sich die Spritzdüse um 80 - 180° um die Vorderkante (3) dreht, wodurch ein Verbindungssegment geformt wird,
einen dritten Unterschritt C5, wobei sich die Spritzdüse von der Umrandung (7) weg zu der zweiten Seite (6) des Schaufelblattabschnitts (2) bewegt, wodurch ein Segment (91) des zweiten Streifens (9) geformt wird.

6. Verfahren nach Anspruch 5, wobei Schritt C nach Unterschritt C5 die folgenden Unterschritte umfasst:

einen vierten Unterschritt C6, wobei sich die Spritzdüse von der zweiten Seite des Schaufelblattabschnitts in Richtung der Umrandung bewegt, wodurch ein Segment des zweiten Streifens angrenzend an den vorhergehenden geformt wird,
einen fünften Unterschritt C7, wobei sich die Spritzdüse um 80 - 180 ° um die Vorderkante dreht, wodurch ein Verbindungssegment geformt wird,
einen sechsten Unterschritt C8, wobei sich die Spritzdüse von der Umrandung weg zu der ersten Seite des Schaufelblattabschnitts bewegt, wodurch ein Segment des ersten Streifens angrenzend an den vorhergehenden geformt wird;
wobei die Spritzdüse nach Unterschritt C5 und vor Unterschritt C6 in Längsrichtung verschoben wird.

7. Verfahren nach einem der vorstehenden Ansprüche, wobei die Streifen (108) mehrere parallele Segmente (181) parallel zur Vorderkante (103) umfassen.

Revendications

1. Procédé de formation d'une structure protectrice sur une aube de turbomachine (1), dans lequel, le procédé comprend les étapes successives suivantes :

A) fourniture d'une aube de turbomachine (1) comprenant une partie de profil aérodynamique (2) ayant un bord d'attaque (3) et un bord de fuite (4) et des premier et deuxième côtés (5, 6) reliant le bord d'attaque (3) et le bord de fuite (4),
B) formation d'une bordure protectrice (7) sur le bord d'attaque (3) par revêtement au laser, et
C) formation de première et deuxième bandes protectrices (8, 9) sur les premier et deuxième côtés (5, 6) de manière adjacente à la bordure par pulvérisation à froid à travers une buse de pulvérisation ;
dans lequel la buse de pulvérisation se déplace au moins d'un côté (5,6) de la partie de profil aérodynamique (2) en direction de la bordure (7) pour former une bande (8, 9) et tourne autour du bord d'attaque (3) afin de former la bande (8, 9) adjacente au bord d'attaque (3) et à la bordure (7).

2. Procédé selon la revendication 1, dans lequel la première bande protectrice (8) est formée avant ou après ou en même temps que les deuxièmes bandes protectrices (9).

3. Procédé selon la revendication 1 ou la revendication 2, dans lequel les bandes (8, 9) comprennent une pluralité de segments parallèles (81, 91) transversaux au bord d'attaque (3).

4. Procédé selon une quelconque revendication précédente, dans lequel, à l'étape C, la buse de pulvérisation se déplace d'un côté (5, 6) de la partie de profil aérodynamique en direction de la bordure (7) et tourne d'au moins 40°, de préférence de 80 à 90°.

5. Procédé selon une quelconque revendication précédente, dans lequel l'étape C comprend :

une première sous-étape C3 dans lequel la buse de pulvérisation se déplace du premier côté (5) de la partie de profil aérodynamique (2) en direction de la bordure (7) en formant ainsi un segment (81) de la première bande (8),
une deuxième sous-étape C4 dans lequel la buse de pulvérisation tourne autour du bord d'attaque (3) de 80 à 180° en formant ainsi un segment de liaison,
une troisième sous-étape C5 dans lequel la buse de pulvérisation s'éloigne de la bordure (7) vers le deuxième côté (6) de la partie de profil aérodynamique (2) en formant ainsi un segment (91) de la deuxième bande (9).

6. Procédé selon la revendication 5, dans lequel l'étape C comprend les sous-étapes suivantes après la sous-étape C5 :

une quatrième sous-étape C6 dans lequel la buse de pulvérisation se déplace du deuxième côté de la partie de profil aérodynamique en direction de la bordure en formant ainsi un segment de la deuxième bande adjacent au précédent,
une cinquième sous-étape C7 dans lequel la buse de pulvérisation tourne autour du bord d'attaque de 80 à 180° en formant ainsi un segment de liaison,
une sixième sous-étape C8 dans lequel la buse de pulvérisation s'éloigne de la bordure vers le premier côté de la partie de profil aérodynami-

que en formant ainsi un segment de la première bande adjacent au précédent ;
dans lequel la buse de pulvérisation est déplacée longitudinalement après la sous-étape C5 et avant la sous-étape C6.

7. Procédé selon une quelconque revendication précédente, dans lequel les bandes (108) comprennent une pluralité de segments parallèles (181) parallèles au bord d'attaque (103).

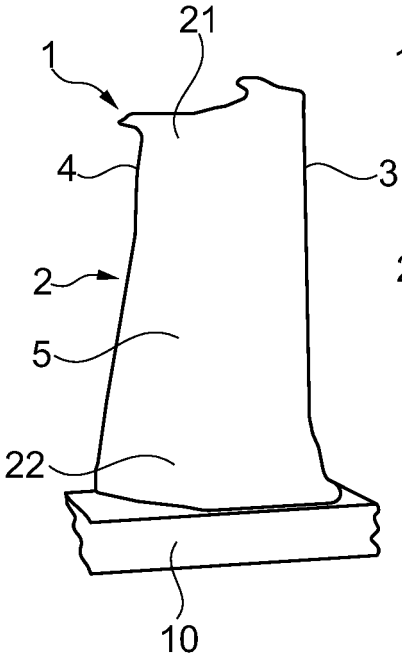

Fig. 1

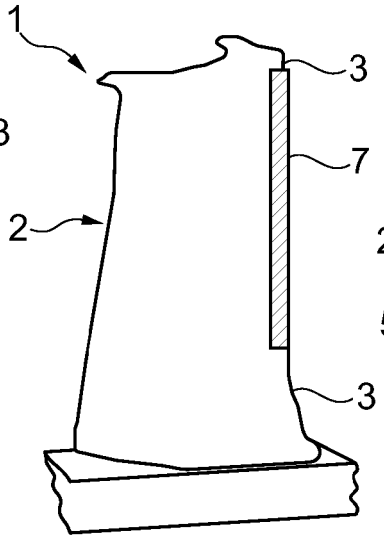

Fig. 2

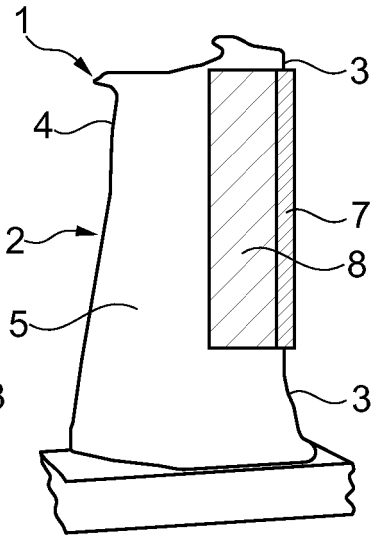

Fig. 3

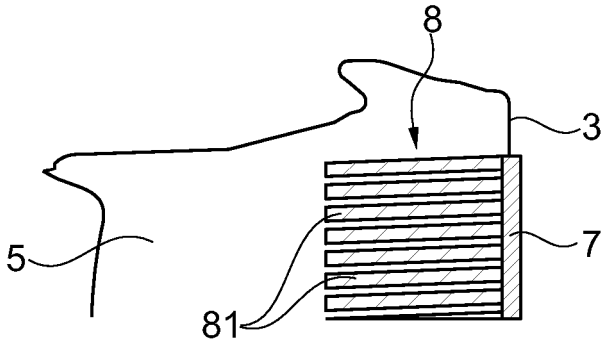

Fig. 4

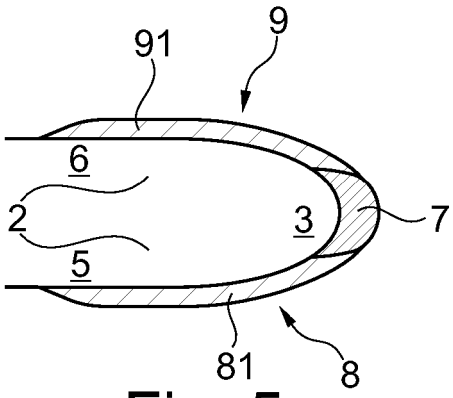

Fig. 5

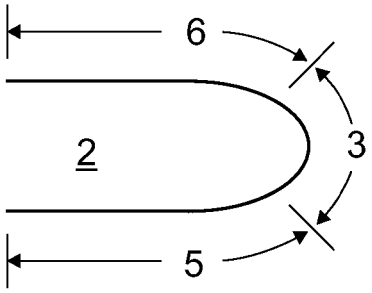

Fig. 6

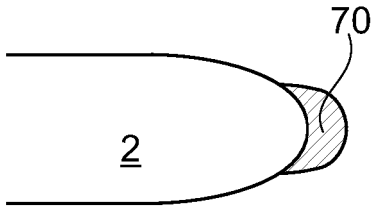

Fig. 7

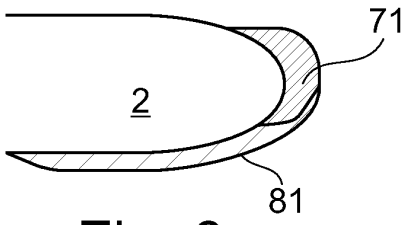

Fig. 8

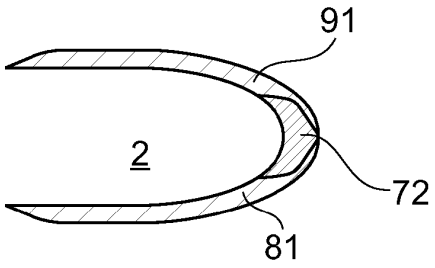

Fig. 9

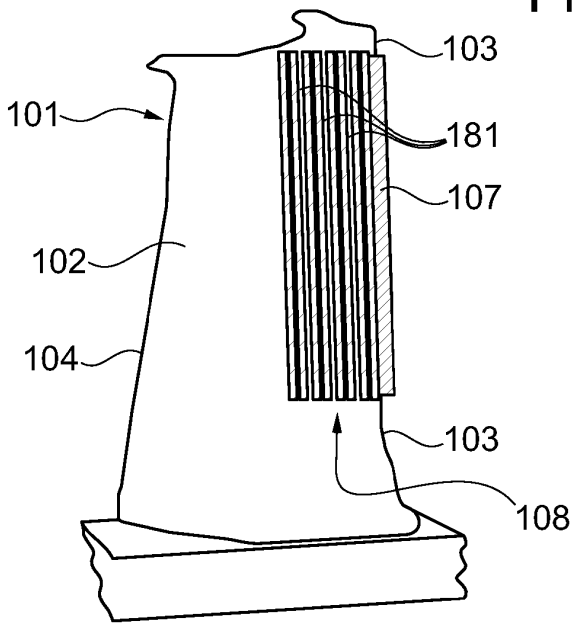

Fig. 10

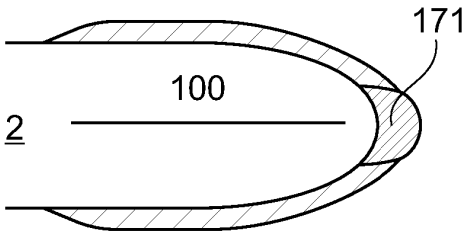

Fig. 11

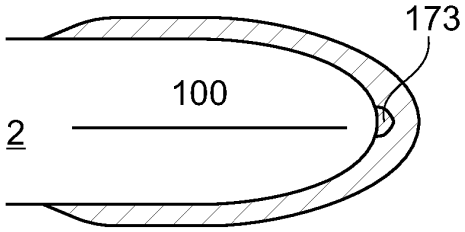

Fig. 13

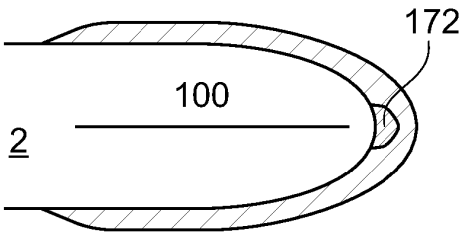

Fig. 12

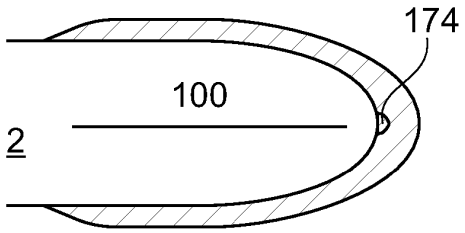

Fig. 14

REFERENCES CITED IN THE DESCRIPTION

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