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

(11) EP 2 942 484 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
**11.11.2015 Bulletin 2015/46**

(51) Int Cl.:
***F01D 5/16*** *(2006.01)* ***F01D 5/18*** *(2006.01)*

(21) Application number: **15166907.4**

(22) Date of filing: **08.05.2015**

(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**
Designated Extension States:
**BA ME**
Designated Validation States:
**MA**

(30) Priority: **09.05.2014 US 201461991328 P**

(71) Applicant: **United Technologies Corporation**
**Hartford, CT 06101 (US)**

(72) Inventors:
- **SNYDER, Daniel A.**
  **Hartford, CT Connecticut 06101 (US)**
- **THORNTON, Lane**
  **Hartford, CT Connecticut 06101 (US)**
- **SIMPSON, Alex J.**
  **Hartford, CT Connecticut 06101 (US)**

(74) Representative: **Stevens, Jason Paul**
**Dehns**
**St Bride's House**
**10 Salisbury Square**
**London**
**EC4Y 8JD (GB)**

(54) **BLADE ELEMENT CROSS-TIES**

(57) The invention concerns a blade element for a gas turbine engine and methods of manufacturing said blade elements.

In one embodiment, a blade element 100 includes a first inner surface 108 of the blade element, wherein the first inner surface 108 is associated with a first outer blade surface 106 of the blade element, and a second inner surface 109 of the blade element, wherein the second inner surface 109 is associated with a second outer blade surface 107 of the blade element and wherein the second inner surface 109 is opposite from the first inner surface 108. The blade element 100 also includes a cross-tie $130_1$ configured to connect the first inner surface 108 to the second inner surface 109, wherein the cross-tie $130_1$ is positioned along a trailing edge 110 of the blade element 100 and the cross-tie $130_1$ is configured to reduce vibration mode effects of the blade element 100.

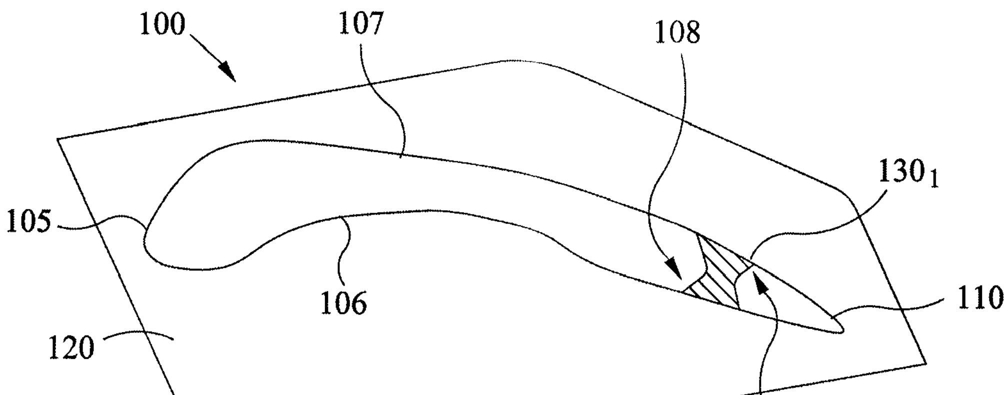



FIG. 1B

EP 2 942 484 A1

## Description

CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This application claims priority to U.S. Provisional Application No. 61/991,328 filed on May 09, 2014 and titled Blade Element Cross-Ties, the disclosure of which is hereby incorporated by reference in its entirety.

FIELD

**[0002]** The present disclosure relates generally to components for a gas turbine engine, and more particularly to blade elements including cross-ties.

BACKGROUND

**[0003]** A gas turbine engine typically includes one or more blades in each of the compressor and turbine sections of the engine. These components are exposed to high-speed air/gas flow during operation. In addition, gas turbine engine components are exposed to high temperatures. As such, airfoils are typically provided with cooling channels. Airfoil structures experience high levels of stress during operation which may limit component operation life. There exists a desire to extend the operational life of components.

**[0004]** Manufacturing of airfoil components can include using ceramic cores to form passages in airfoils. Conventional methods include the use of stiffening rods to supporting cast elements. These rods are removed with cast elements during manufacture of the component. Accordingly, there rods do not provide structural support during operation.

**[0005]** While there have been approaches to fabricating components, there is a need in the art to extend component life and improve integrity.

BRIEF SUMMARY OF THE EMBODIMENTS

**[0006]** Disclosed and claimed herein are blade elements and methods for making blade elements including cross-ties. In one embodiment, a blade element for a gas turbine engine includes a first inner surface of the blade element, wherein the first inner surface is associated with a first outer blade surface of the blade element, and a second inner surface of the blade element, wherein the second inner surface is associated with a second outer blade surface of the blade element and wherein the second inner surface is opposite from the first inner surface. The blade element also includes a cross-tie configured to connect the first inner surface to the second inner surface, wherein the cross-tie is positioned along a trailing edge of the blade element and the cross-tie is configured to reduce vibration mode effects of the blade element.

**[0007]** According to another embodiment, a method for manufacturing a blade element of a gas turbine engine includes forming a first blade surface of the blade element, wherein the first blade surface includes a first inner surface, and forming a second blade surface of the blade element, wherein the second blade surface includes a second inner surface and wherein the second inner surface is opposite from the first inner surface. The method also includes forming a cross-tie configured to connect the first inner surface to the second inner surface along a trailing edge of the blade element, wherein the cross-tie is positioned and configured to reduce vibration mode effects of the blade element.

**[0008]** Other aspects, features, and techniques will be apparent to one skilled in the relevant art in view of the following detailed description of the embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

**[0009]** The features, objects, and advantages of the present disclosure will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIGS. 1A-1C depict graphical representations of a blade element according to one or more embodiments;

FIG. 2A depicts a graphical representation of a blade element cross-tie according to one or more embodiments;

FIG. 2B depicts a cross-sectional view of the cross-tie of FIG. 2A according to one or more embodiments;

FIG. 3 depicts a graphical representation of a blade element cast according to one or more embodiments; and

FIG. 4 depicts a process for manufacturing a blade element according to one or more embodiments.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

Overview and Terminology

**[0010]** One aspect of the disclosure relates to blade elements for a gas turbine engine. According to one embodiment, a blade element, such as fan blades, turbine blades and vanes, may be provided including one or more cross-ties. As used herein, a cross-tie is a structural element configured to provide rigidity to an interior passage or hollow section of a blade element. According to one or more embodiments, each cross-tie may have a curved profile with surface blended to inner walls of a blade element. According to another embodiment cross-ties may include a non-circular cross section. Cross-ties may be placed and configured to provide support and rigidity to unsupported areas of a blade element. Cross-ties may additionally allow for internal connections within a blade element without restricting airflow or changing heat transfer of the blade element.

**[0011]** Another aspect of the disclosure is directed to manufacturing blade elements to include one or more cross-ties. According to one embodiment, a cast having positives and negatives may be formed for manufacturing a blade element having one or more cross-ties.

**[0012]** As used herein, the terms "a" or "an" shall mean one or more than one. The term "plurality" shall mean two or more than two. The term "another" is defined as a second or more. The terms "including" and/or "having" are open ended (e.g., comprising). The term "or" as used herein is to be interpreted as inclusive or meaning any one or any combination. Therefore, "A, B or C" means "any of the following: A; B; C; A and B; A and C; B and C; A, B and C". An exception to this definition will occur only when a combination of elements, functions, steps or acts are in some way inherently mutually exclusive.

**[0013]** Reference throughout this document to "one embodiment," "certain embodiments," "an embodiment," or similar term means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, the appearances of such phrases in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner on one or more embodiments without limitation.

**[0014]** Referring now to the figures, FIGS. 1A-1C depict graphical representations of a blade element according to one or more embodiments. Referring first to FIG. 1A, blade element 100 is shown including leading edge 105, blade surface 106 (e.g., a first blade surface) and trailing edge 110. Blade element 100 may be one of a turbine blade, fan blade, vane, and gas turbine engine component. FIG. 1A depicts blade element 100 including base structure 120.

**[0015]** According to one embodiment, blade element 100 may include one or more cross-ties configured to connect a first blade surface, such as an inner surface of blade surface 106, to a second inner blade surface. By way of example, cross-ties may connect inner surfaces of the blade element. Cross-ties may be positioned near and/or along trailing edge 110 of blade element 100, wherein the cross-tie is positioned and configured to reduce vibration mode effects of the blade element 100. As discussed herein, vibration mode effects can relate to one or more of blade surface stress, blade surface strain, vibratory stress, vibratory strain, and blade deformation. Cross-ties may be configured to provide stiffening to reduce one or more of the vibratory effects. It should be appreciated that the frequency of vibratory stress may be driven up or down. While stress should be generally reduced everywhere in blade element 100, there are situations where the vibratory frequency needs to be driven upward. Thus, cross-ties as discussed herein may be configured to stress and/or strain associated with the vibratory mode of a blade element.

**[0016]** In one embodiment, cross-ties of blade element 100 are positioned between 20-90% of a span length, shown generally as area 115 in FIG. 1A, of blade element 100. The trailing edge portion of the blade may relate to portions of the blade element 100 near trailing edge 110. Blade element 100 may include a plurality of cross-ties along the trailing edge 110 in area 115. Each cross-tie may be formed integrally with an inner surface of blade element 100 within a particular area shown as section 116. Section or area 116 is shown in more detail with respect to FIGS. 2A-2B. In some embodiments, cross-ties may be positioned in other portions of blade element 100.

**[0017]** FIG. 1B depicts a top down representation of blade element 100. As shown in FIG. 1B, blade element 100 includes a first blade surface of the blade element, blade surface 106 with corresponding first inner surface 108, and a second blade surface, blade surface 107 with corresponding second inner surface 109. Blade surface 108 is opposite from blade surface 109, wherein the blade surfaces are between leading edge 105 and trailing edge 110. In one embodiment, blade surface 108 is opposite from blade surface 109 meaning the surfaces are on opposing ends of an interior portion. It can be appreciated that surfaces 108 and 109 may be parallel, substantially parallel, or not parallel. It can also be appreciated that surfaces 108 and 109 may not correspond to the surface shape characteristics of surfaces 106 and 107. By way of example, while surfaces 106 and 107 may be smooth, surfaces 108 and 109 may be formed on one or more protrusions of other interior features of a blade element. As further depicted in FIG. 1B, blade element 100 includes a representation of cross-tie $130_1$. Cross-tie $130_1$ is configured to connect blade surface 106 to blade surface 107. Cross-tie $130_1$ is positioned near trailing edge 110 of blade element 100. Cross-tie $130_1$ may be configured to reduce vibration mode of blade element 100 by providing increased stiffness for walls of the blade element.

**[0018]** FIG. 1C depicts a cut-away representation of blade element 100. According to one embodiment, blade element 100 may include cooling area 125 to provide cooling air/air flow for cooling blade element 100. Cooling area 125 may be one or more hollow sections of blade element 100. Cross-ties $130_{1-n}$ are shown relative to inner surface 109 and near trailing edge 110. In certain embodiments, cross-ties $130_{1-n}$ may be positioned to provide structural integrity without restricting airflow.

**[0019]** FIG. 2A depicts a graphical representation of a blade element cross-tie according to one or more embodiments. In FIG. 2A, section 200 of a blade element (e.g., blade element 100) includes cross-tie 205. Cross-tie 205 includes a first portion blended to an inner wall of blade surface 206, a second portion blended to an inner wall of blade surface 207, and a non-circular cross-section 210 between the first and second portions. As shown in FIG. 2A, non-circular cross-section 210 is reduced in size relative to the first and second portions of the cross-tie blended to blade surfaces. Cross-tie 205 may be configured to provide a connection between surfaces 206 and 207 and provide both in-plane (shear) and out-of-plane (compressive/tensile) support. By providing stiffening, cross-tie 205 can reduce the extent to which surfaces 206 and 207 participate in the vibration mode of the blade element.

**[0020]** FIG. 2B depicts a cross-sectional view of the cross-tie of FIG. 2A according to one or more embodiments. Blade element section 250 is a cross sectional view along reference line A-A of FIG. 2A, which is associated with the central axis of the cross-tie 205. As shown in FIG. 2A, cross-tie 205 is formed to include a non-circular blend between first and second portions of the cross-tie blended to blade surfaces. Non-circular curved/bending is shown by arcs 255, 260, 265 and 270. Cross-tie 205 includes a long axis oriented with the direction of centrifugal pull of a blade element (e.g., blade element 105). According to one embodiment, cross-tie 205 increases stability of the blade element by supporting the first and second blade element surfaces in a hollow section of the blade element. Cross-tie 205 may be configured to provide in-plane and out-of-plane support for the blade element. In-plane support provided by the blade element may relate support along an axis of cross-tie 205, while out-of-plane support may relate to support for vibratory and steady state stress of the blade element in general.

**[0021]** FIG. 3 depicts a graphical representation of a blade element cast according to one or more embodiments. According to one embodiment, blade elements (e.g., blade element 100) may be cast to include one or more cross-ties. Cast 300 is a simplified representation of a cast element including negatives and positives that may be employed to fabricate a blade element as described herein. As shown in FIG. 3, cast 300 includes a plurality of negatives, shown as $305_{1-n}$, to allow for cross-ties to be formed. Cast 300 also includes a plurality of positives, shown as $310_{1-n}$, to allow for cooling passages to be formed.

**[0022]** FIG. 4 depicts a process for manufacturing a blade element (e.g., blade element 100) according to one or more embodiments. Process 400 may be initiated at block 405 with determining one or more cross-tie locations for a blade element. By way of example, modelling of a blade element may indicate one or more locations where additional stiffness or an internal connection is required. In certain embodiments, determining one or more cross-tie locations for the blade element includes modelling a blade element for one or more of vibratory frequency, vibratory mode shape and vibratory stress.

**[0023]** At block 410, a cast (e.g., cast 300) for the blade element may be generated. According to one embodiment, a cast may be formed at block 410 to include one or more negatives and positives, to form cross-ties and cooling paths.

**[0024]** Process 400 may continue to block 415 to fabricate a blade element based on the cast generated at block 410 to include one or more cross-ties. In one embodiment, fabricating a blade element of a gas turbine engine at block 415 includes forming a first blade surface of the blade element, and forming a second blade surface of the blade element, wherein the second blade surface is opposite from the first blade surface. Fabricating a blade element of a gas turbine engine at block 415 may also include forming one or more cross-ties configured to connect the inner surface of a first blade surface to the inner surface of a second blade surface on a trailing edge of the blade element. Forming cross-ties at block 415 can include forming a plurality of cross-ties along the trailing edge of the blade element.

**[0025]** While this disclosure has been particularly shown and described with references to exemplary embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the claimed embodiments.

## Claims

**1.** A blade element for a gas turbine engine, the blade element comprising:

a first inner surface of the blade element, wherein the first inner surface is associated with a first outer blade surface of the blade element;
a second inner surface of the blade element, wherein the second inner surface is associated with a second outer blade surface of the blade element and wherein the second inner surface is opposite from the first inner surface; and
a cross-tie configured to connect the first inner surface to the second inner surface, wherein the cross-tie is positioned along a trailing edge of the blade element and the cross-tie is configured to reduce vibration mode effects of the blade element.

**2.** The blade element of claim 1, wherein the cross-tie includes a first portion blended to the first inner surface, a second portion blended to the second inner surface, and a non-circular cross-section between the first and second portions.

**3.** The blade element of claim 2, wherein the non-circular cross-section is reduced in size relative to the first and second portions of the cross-tie.

**4.** The blade element of claim 2, wherein the non-circular cross-section is formed to include a non-circular blend between first and second portions of the cross-tie blended to blade surfaces.

**5.** The blade element of any preceding claim, wherein the cross-tie includes a long axis oriented with the direction of centrifugal pull of the blade element.

6. The blade element of any preceding claim, wherein the cross-tie increases stability of the blade element by supporting the first and second blade element surfaces in a hollow section of the blade element.

7. The blade element of any preceding claim, wherein the second inner surface is opposite from the first inner surface within at least one of cooling passage and hollow portion of the blade element.

8. The blade element of any preceding claim, wherein vibration mode effects include at least one of blade surface stress, blade surface strain, vibratory stress, vibratory strain, and blade deformation.

9. The blade element of any preceding claim, wherein said blade element includes a plurality of cross-ties along the trailing edge of the blade element.

10. The blade element of claim 9, wherein cross-ties of the blade element are positioned between 20 - 90% of a span length of the blade element.

11. A method for fabricating a blade element of a gas turbine engine, as claimed in any of claims 1 to 5, 9 and 10, the method comprising:

forming a first blade surface of the blade element, wherein the first blade surface includes the first inner surface;
forming a second blade surface of the blade element, wherein the second blade surface includes the second inner surface and wherein the second inner surface is opposite from the first inner surface; and
forming the cross-tie configured to connect the first inner surface to the second inner surface along a trailing edge of the blade element, wherein the cross-tie is positioned and configured to reduce vibration mode effects of the blade element.

12. The method of claim 11, wherein the cross-tie increases stability of the blade element by supporting the first and second blade element surfaces in at least one of a cooling passage and hollow portion of the blade element.

13. The method of claim 11 or claim 12, wherein forming cross-ties includes forming a plurality of cross-ties along the trailing edge of the blade element.

14. The method of any of claims 11 to 13, further comprising determining one or more cross-tie locations for the blade element.

15. The method of claim 14, wherein determining one or more cross-tie locations for the blade element includes modelling a blade element for one or more of vibratory frequency, vibratory mode shape and vibratory stress.

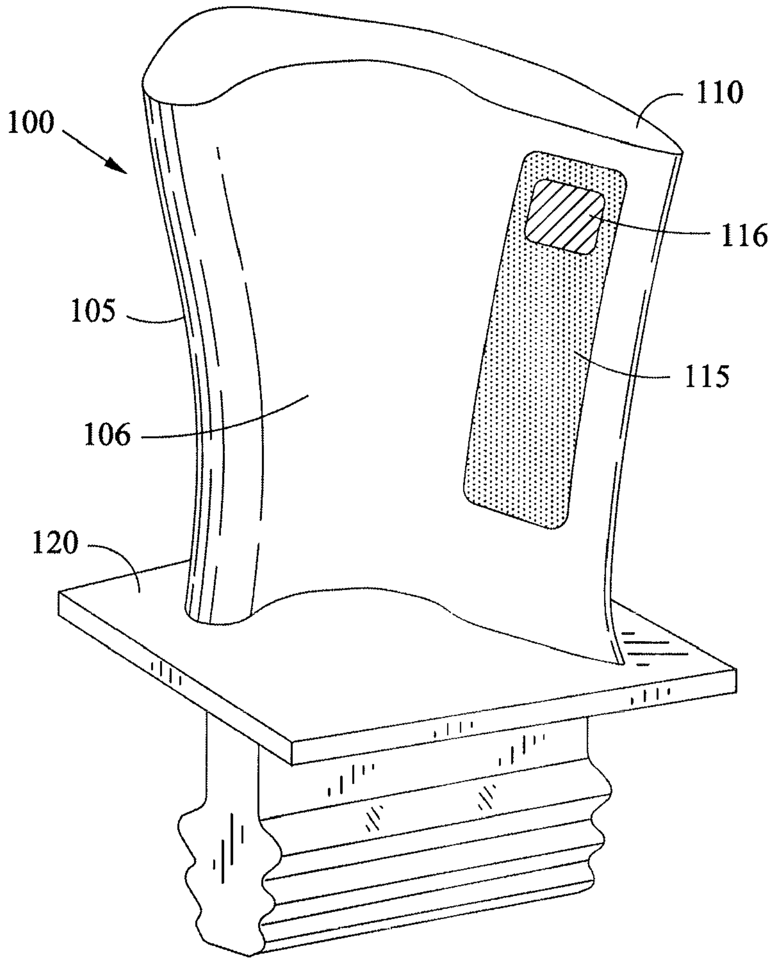



*FIG. 1A*

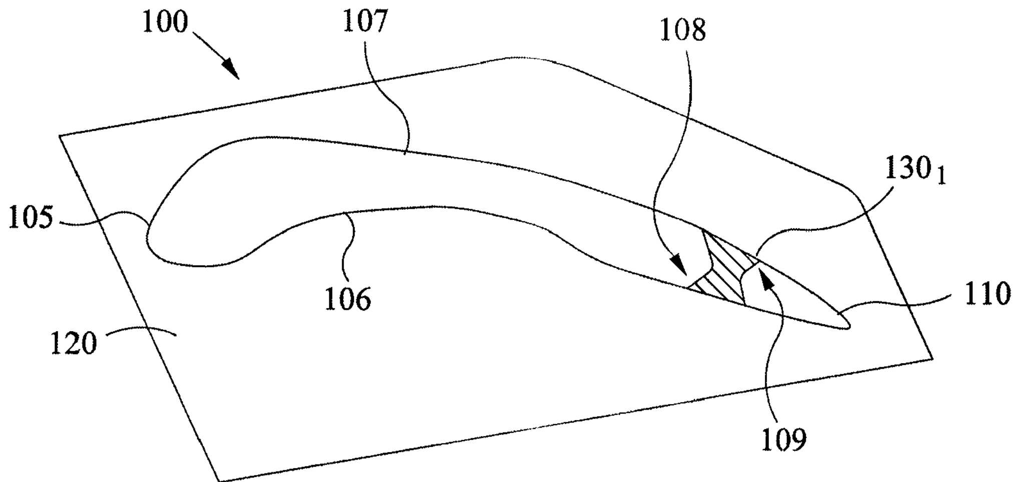



*FIG. 1B*

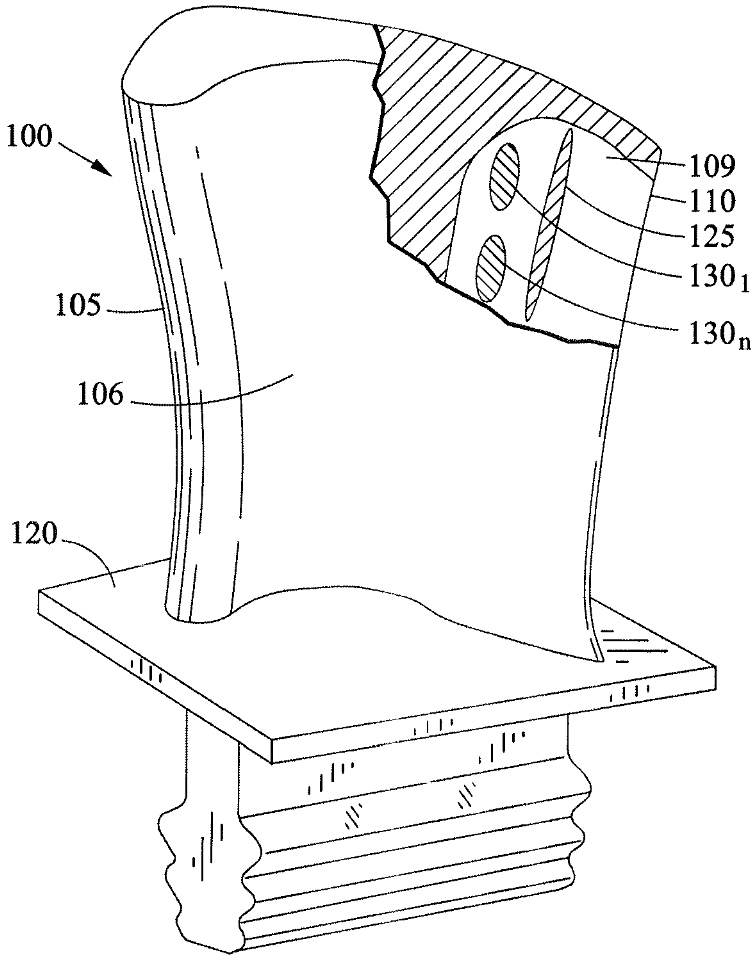
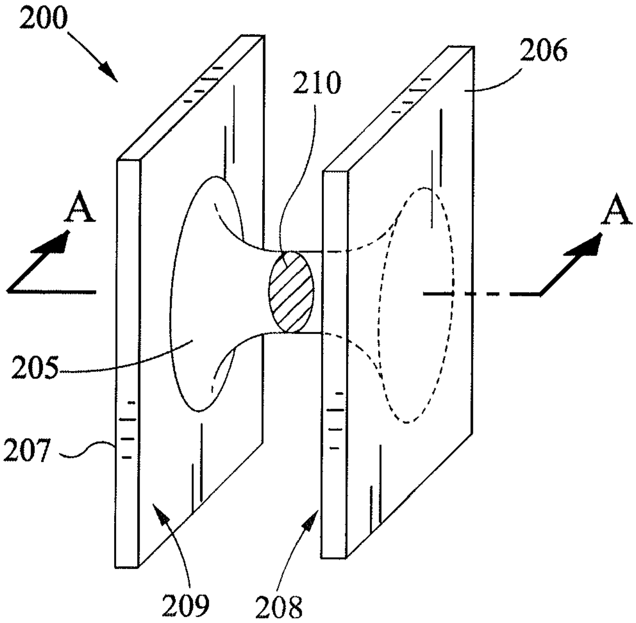
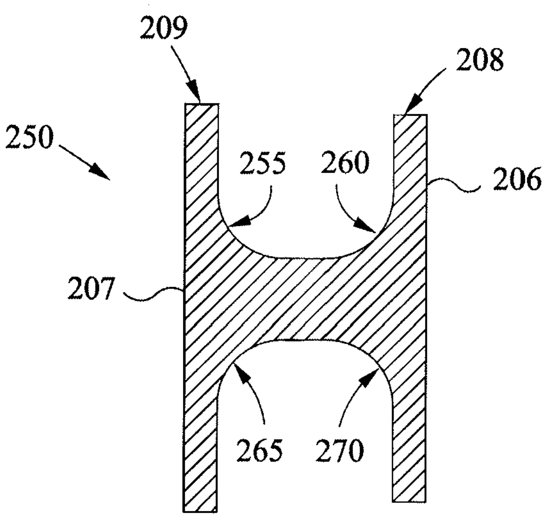



*FIG. 1C*



200
206
210
A
A
205
207
209
208


*FIG. 2A*



209
208
250
255
260
206
207
265
270


*FIG. 2B*

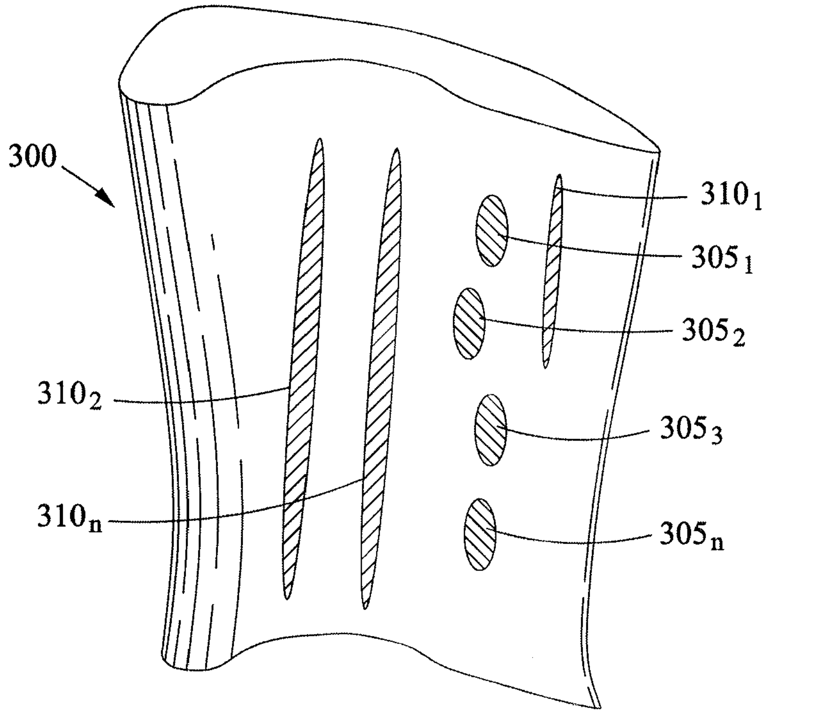

300
$310_1$
$305_1$
$305_2$
$310_2$
$305_3$
$310_n$
$305_n$

*FIG. 3*

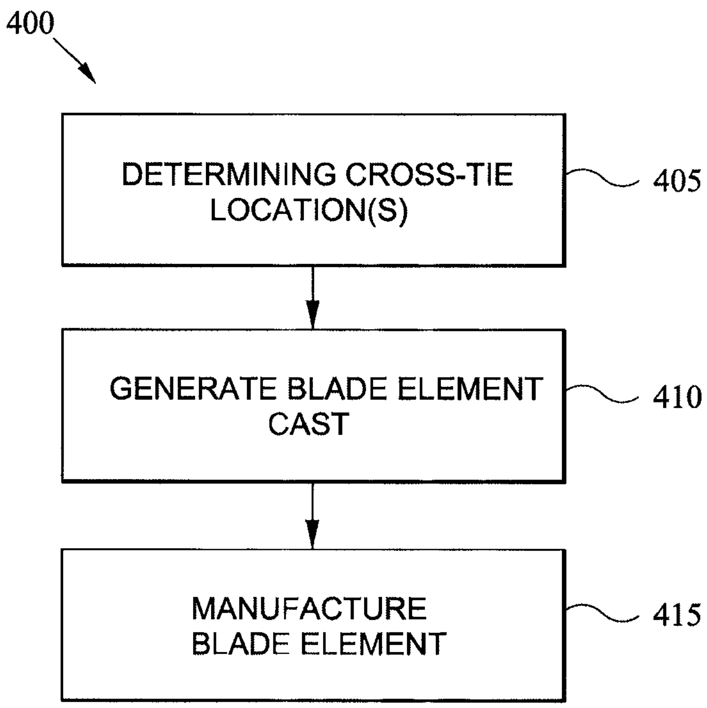

400
DETERMINING CROSS-TIE LOCATION(S)
405
GENERATE BLADE ELEMENT CAST
410
MANUFACTURE BLADE ELEMENT
415

*FIG. 4*

Europäisches Patentamt
European Patent Office
Office européen des brevets

# EUROPEAN SEARCH REPORT

Application Number
EP 15 16 6907

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
|---|---|---|---|
| X | EP 1 431 514 A2 (GEN ELECTRIC [US]) 23 June 2004 (2004-06-23) * paragraphs [0050] - [0052]; figures 4,5 * | 1-15 | INV. F01D5/16 F01D5/18 |
| X | US 2005/084380 A1 (FETT STEVEN J [CA] ET AL) 21 April 2005 (2005-04-21) * paragraphs [0024], [0025], [0031]; figures 3A,4 * | 1-6, 8-11,14, 15 | |
| X | US 7 780 414 B1 (LIANG GEORGE [US]) 24 August 2010 (2010-08-24) * column 5, line 36 - column 6, line 22; figures 3,4 * | 1-14 | |
| X | US 4 278 400 A (YAMARIK GEORGE J ET AL) 14 July 1981 (1981-07-14) * column 3, line 21 - line 39; figure 1 * | 1-14 | |

TECHNICAL FIELDS SEARCHED (IPC)

F01D

The present search report has been drawn up for all claims

1

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 10 September 2015 | Pileri, Pierluigi |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 15 16 6907

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

10-09-2015

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| EP 1431514 A2 | 23-06-2004 | CN 1512036 A | 14-07-2004 |
| | | EP 1431514 A2 | 23-06-2004 |
| | | JP 4540973 B2 | 08-09-2010 |
| | | JP 2004197740 A | 15-07-2004 |
| | | US 2004115053 A1 | 17-06-2004 |
| US 2005084380 A1 | 21-04-2005 | CA 2542285 A1 | 21-04-2005 |
| | | DE 602004008950 T2 | 12-06-2008 |
| | | EP 1673518 A1 | 28-06-2006 |
| | | JP 2007508486 A | 05-04-2007 |
| | | US 2005084380 A1 | 21-04-2005 |
| | | WO 2005035947 A1 | 21-04-2005 |
| US 7780414 B1 | 24-08-2010 | NONE | |
| US 4278400 A | 14-07-1981 | NONE | |

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

## REFERENCES CITED IN THE DESCRIPTION

*This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.*

### Patent documents cited in the description

- US 61991328 A **[0001]**