



(51) International Patent Classification:

C23C 4/08 (2006.01) C23C 10/10 (2006.01)
C23C 4/18 (2006.01) C23C 10/12 (2006.01)
C23C 10/02 (2006.01) C23C 10/14 (2006.01)
C23C 10/06 (2006.01) C23C 10/56 (2006.01)
C23C 10/08 (2006.01) C23C 10/60 (2006.01)

(21) International Application Number:

PCT/EP2009/050743

(22) International Filing Date:

23 January 2009 (23.01.2009)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

08003968.8 4 March 2008 (04.03.2008) EP

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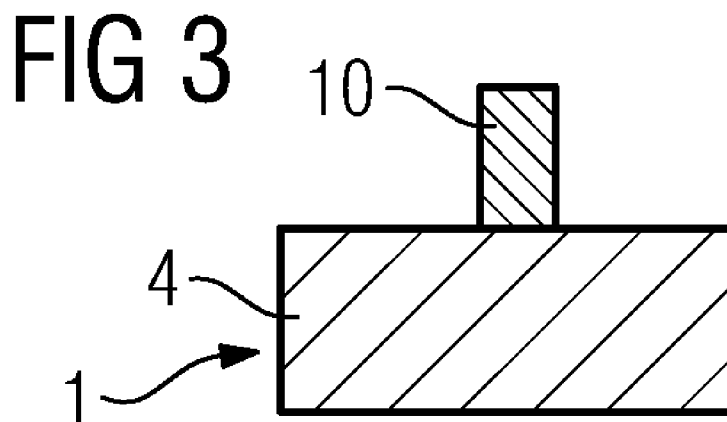
(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ,
CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ,
EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR,
KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME,
MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO,
NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG,
SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA,
UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM,
ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ,
TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE,
ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR),
OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML,
MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: A MCrAlY ALLOY, METHODS TO PRODUCE A MCrAlY LAYER AND A HONEYCOMB SEAL



(57) Abstract: Honeycomb seals are also attacked by oxidation and/or corrosion. A MCrAlY coating (7) on the honeycomb cells (13) improves the lifetime of the honeycomb cells (13) and therefore for the lifetime of the honeycomb seal (1).

A MCrAlY alloy, methods to produce a MCrAlY layer and a honeycomb seal

5 The invention relates to a MCrAlY alloy according to claim 1, methods to produce a MCrAlY layer according to claims 7, 8 and a honeycomb seal according to claim 19.

10 Substrates are often coated with a protective layer because the material of the substrate does not offer good oxidation or corrosion resistance. By contrast the coatings have good corrosion resistance but not good mechanical properties.

15 Both gas turbine and jet engine manufacturers must seal and isolate certain sections of an engine thereby controlling the passages of gases through a modern engine. It is well known to produce seals between sections by impressing a sharpened part feature called a seal tooth into a very crushable opposing part called an honeycomb seal.

20 The materials used for the honeycomb seals are selected to maintain their ability to be crushed by the sharp seal tooth. These seals are generally made of numerous pockets with six side walls similar to the pattern of honeycombs in nature. 25 They are skived into layers about 0.2" thick (0.6cm) and then laid into a curved piece to fit around the engine. These pieces are called shrouds. To hold the honeycomb in, it has been the practice to braze the hexagonal shaped seal material into a shroud pocket.

30 To improve the life of the seals, some engine manufacturers also fill the small hexagonal pockets with abradable materials and then braze this into the shroud as well. Honeycomb seals also undergo corrosion and oxidation, which decreases the life time of the component.

35 These seals work acceptably well and have been in use for a number of years. As the sulfur levels have increased in fuels and harder damage has occurred to the seals during engine

operation. The mechanism of damage has been shown to be hot corrosion enhanced by the sulfur levels in the fuels.

There exists a need for a more corrosion/oxidation resistant material to fabricate the cells from. FeCrAlY has been shown to be very hot corrosion/oxidation resistant but nearly impossible to fabricate. For the thin sheets which are needed to form the sidewall of the hexagonal shapes FeCrAlY is too brittle. During manufacturing it may shatter. Hence, while this material is acceptable from the corrosion/oxidation point of view it is not acceptable from difficulties during the metal fabrication.

Therefore is the aim of the invention to solve the problem given above.

The problem is solved by a MCrAlY alloy according to claim 1, methods to produce a MCrAlY layer according to claims 7, 8 and an honeycomb seal according to claim 19.

In the dependent claims further embodiments of the invention are listed which can be combined arbitrarily with each other in order to get additional advantages.

It shows

Figure 1 a honeycomb cells

Figure 2, 3, 4, 5 some embodiments of a honeycomb seal with a coating,

Figure 6 a gas turbine,

Figure 7 a turbine blade in a perspective view.

The figures and the description are only embodiments of the invention.

35

Figure 1 shows several honeycomb cells 13 which have preferably the geometry of a honeycomb (hexagonal).

Such a honeycomb cell 13 consists of six side walls 10,
5 wherein two honeycomb cells 13 have a common side wall 10 in the arrangement of figure 1 if used as seal 1 (Fig. 2).

10 In Figure 2 a partial cross section of a substrate 4 with one honeycomb cell 13 is shown, which form a honeycomb seal 1.

Onto a substrate 4 (shroud) of the honeycomb seal 1 the honeycomb cells 13 with the side walls 10 are brazed (braze not shown).

15 This can be done preferably by applying a brazing layer on the surface 16 of the substrate 4 or applying a braze on the undersides of the side walls 10.

20 According to the invention the sidewalls 10 comprise a M-base metallic material, especially steel or stainless steel, especially 1010 steel.

This steel (as an exemplary example) is then exposed to alloying elements Cr, Al and Y (Fig. 3) to form by diffusion
25 a MCrAlY, here a MCrAlY diffusion area 8 inside the side wall 10 (Fig. 3 → Fig. 4). The diffusion area 8 is only a part of the side wall 10.

The diffusion can preferably also be throughout the wall (Fig. 3 → Fig. 5). This means that nothing of the original
30 sidewall is left. The sidewall 10' consists of a MCrAlY, especially of a FeCrAlY alloy.

Preferably first chromium can be deposition followed by deposition of aluminum, especially doped with Yttrium (Y).

35

Aluminizing can be performed preferably by the well known pack cementation process or other methods.

Preferably Yttrium is coated together with aluminum.

Preferably other alloying elements like Hafnium, titanium or silicon can be added.

The alloying elements are preferably exposed to the substrate by a vapour process, preferably by CVD.
During exposure the elements can be used together or one by one.

Since iron is recognized as a getter for aluminum at least, then the addition of a thick aluminide coating or a thick chromide coating followed by an aluminide coating could be tailored to provide the correct chemistry to meet the composition of FeCrAlY inside the diffusion area (8).
After a following heat treatment for diffusion, a relative soft and ductile 1010 steel of a honeycomb seal was converted into a relatively brittle FeCrAlY via CVD.

The amount of Cr, Al and Y to be diffused into the substrate depends on the amount of Cr, Al (other base elements) already present in the substrate, especially the steel or Fe-based material. This can be controlled by exposure time, temperature and concentration.

Examples

A:

1. providing a substrate 4 with honeycomb cells 13
2. aluminizing
3. optionally an heat treatment to promote diffusion of Al in substrate
4. chromizing
5. optionally an heat treatment to promote diffusion of Cr in Al and into substrate

B:

1. providing a substrate 4 with honeycomb cells 13
2. aluminizing
3. chromizing

4. an heat treatment to promote diffusion of Cr, Al

C:

- 5 1. providing a substrate 4 with honeycomb cells 13 and with
 a braze between honeycomb 13 cells and substrate 4
 2. chromizing
 3. aluminizing
 4. optionally an heat treatment to promote diffusion of Cr,
10 Al

D:

1. providing a substrate 4 with honeycomb cells 13 and with
 a braze between honeycomb 13 cells and substrate 4
15 2. aluminizing
 3. chromizing
 4. optionally an heat treatment to promote diffusion of Cr,
 Al

20 E:

1. providing a substrate 4 with honeycomb cells 13
 2. chromizing
 3. aluminizing
 4. an heat treatment to promote diffusion of Cr, Al
25

F:

1. providing a substrate 4 with honeycomb cells 13
 2. chromizing
 3. optionally an heat treatment to promote diffusion of Al
30 in substrate
 4. aluminizing
 5. optionally an heat treatment to promote diffusion of Cr
 in Al and into substrate

35 Preferably the brazing is preferably accomplished
 simultaneously with the coating process of the coating 7
 (Fig. 6) or of the diffusion area 8 (Fig. 4, 5). That means
 the heat treatment of the brazing procedure is included in

the heating during coating or exposure or a following heat treatment.

By this sequence the advantage of a ductile and easily to be
5 manufactured steel can be used to form the honeycomb cells
and adapt it into shrouds. After that a reduced ductility is
not a problem anymore because no further bending or
mechanical stresses due to manufacturing are induced.

10

According to another example of the invention a protective
MCrAlY coating 7 is applied on the sidewalls 10 (Fig. 6).
Preferably the coating 7 is applied on the honeycomb cells 13
after brazing the honeycomb cells 13 on the substrate 4, so
15 that the braze is also protected by the coating 7.

20

The composition of the coating 7 or diffusion area 8
comprises chromium, aluminum (Al) and yttrium (Y) and balance
M, especially iron (Fe). Especially the FeCrAlY alloy or
coating 7 consists of Fe, Cr, Al and Y.
Optionally the MCrAlY alloy or coating 7 can contain titanium
(Ti), Hafnium (Hf), and/or silicon (Si) which enhance the
corrosion/oxidation behavior of the alloyed or coated steel.
Hafnium (Hf) stabilizes the aluminum oxide which is formed on
25 the outside surface of the MCrAlY alloy wherein silicon (Si)
will permit the formation of an aluminum silicate phase.

30

The phrase "contain" means that the amount of such an element
is at least two times higher than the impurity level of this
element in a MCrAlY alloy or at least two times higher than
the measuring accuracy depending on which is higher.
Especially the MCrAlY alloy or coating 7 consists of Fe, Cr,
Al, Y and at least one element of the group Ti, Hf and/or Si.

35

Preferred ranges of the elements (in wt%) are 18% to 35% Cr,
3% to 15% Al, 0,2% to 2% Yttrium and for the optional
additions up to 3% titanium, up to 3% hafnium and/or up to 3%
silicon.

Adding the low side, the balance would be M, especially iron 80% by weight, and on the high side 39% by weight.

All combinations with the optional elements are preferred
embodiments:

That means: MCrAlY

+ Ti

+ Hf

+ Si

10 + Ti + Hf

+ Ti + Si

+ Hf + Si

+ Ti + Hf + Si.

These seven combinations of the elements of the alloy can be
15 on exclusive (consist) or non-exclusive (comprise) listing of
the MCrAlY or coating 7.

The FeCrAlY coating 7 or diffusion area 8 preferably does not
contain nickel (Ni) and/or does not contain cobalt (Co).

20

The MCrAlY coating 7 can be applied by a coating or exposure
process known in the state of the art by using the adequate
alloy of MCrAlY or preferably by coating the elements Cr, Al
and Y and/or the optional elements separately and forming by
25 diffusion this MCrAlY diffusion area.

Especially, a CVD coating process is used to coat the
honeycomb cells 13 of the honeycomb seals 1.

30 Especially, the honeycomb cell 13 can be filled with an
abradable material, especially a ceramic 19 in order to have
a further improvement of the abrasion behavior of the
honeycomb seal 1 (Fig. 7).

35 The material of the side walls 10 of the honeycomb cells 1 is
preferably steel or stainless steel.

The best results with the diffusion areas 8 were got with a iron based substrate to obtain a FeCrAlY alloy.

Figure 8 shows, by way of example, a partial longitudinal section through a gas turbine 100.

In the interior, the gas turbine 100 has a rotor 103 which is mounted such that it can rotate about an axis of rotation 102, has a shaft and is also referred to as the turbine rotor.

An intake housing 104, a compressor 105, a, for example, toroidal combustion chamber 110, in particular an annular combustion chamber, with a plurality of coaxially arranged burners 107, a turbine 108 and the exhaust-gas housing 109 follow one another along the rotor 103.

The annular combustion chamber 110 is in communication with a, for example, annular hot-gas passage 111, where, by way of example, four successive turbine stages 112 form the turbine 108.

Each turbine stage 112 is formed, for example, from two blade or vane rings. As seen in the direction of flow of a working medium 113, in the hot-gas passage 111 a row of guide vanes 115 is followed by a row 125 formed from rotor blades 120.

The guide vanes 130 are secured to an inner housing 138 of a stator 143, whereas the rotor blades 120 of a row 125 are fitted to the rotor 103 for example by means of a turbine disk 133.

A generator (not shown) is coupled to the rotor 103.

While the gas turbine 100 is operating, the compressor 105 sucks in air 135 through the intake housing 104 and compresses it. The compressed air provided at the turbine-side end of the compressor 105 is passed to the burners 107, where it is mixed with a fuel. The mix is then burnt in the combustion chamber 110, forming the working medium 113. From there, the working medium 113 flows along the hot-gas passage 111 past the guide vanes 130 and the rotor blades 120. The

working medium 113 is expanded at the rotor blades 120, transferring its momentum, so that the rotor blades 120 drive the rotor 103 and the latter in turn drives the generator coupled to it.

5

While the gas turbine 100 is operating, the components which are exposed to the hot working medium 113 are subject to thermal stresses. The guide vanes 130 and rotor blades 120 of the first turbine stage 112, as seen in the direction of flow
10 of the working medium 113, together with the heat shield bricks which line the annular combustion chamber 110, are subject to the highest thermal stresses.

To be able to withstand the temperatures which prevail there, they can be cooled by means of a coolant.

15 Substrates of the components may likewise have a directional structure, i.e. they are in single-crystal form (SX structure) or have only longitudinally oriented grains (DS structure).

By way of example, iron-based, nickel-based or cobalt-based
20 superalloys are used as material for the components, in particular for the turbine blade or vane 120, 130 and components of the combustion chamber 110.

Superalloys of this type are known, for example, from
EP 1 204 776 B1, EP 1 306 454, EP 1 319 729 A1, WO 99/67435
25 or WO 00/44949; these documents form part of the disclosure with regard to the chemical composition of the alloys.

The guide vane 130 has a guide vane root (not shown here) facing the inner housing 138 of the turbine 108 and a guide
30 vane head at the opposite end from the guide vane root. The guide vane head faces the rotor 103 and is fixed to a securing ring 140 of the stator 143.

35 Figure 9 shows a perspective view of a rotor blade 120 or guide vane 130 of a turbo machine, which extends along a longitudinal axis 121.

The turbo machine may be a gas turbine of an aircraft or of a power plant for generating electricity, a steam turbine or a compressor.

5 The blade or vane 120, 130 has, in succession along the longitudinal axis 121, a securing region 400, an adjoining blade or vane platform 403 and a main blade or vane part 406 as well as a blade or vane tip 415.
As a guide vane 130, the vane 130 may have a further platform
10 (not shown) at its vane tip 415.

A blade or vane root 183, which is used to secure the rotor blades 120, 130 to a shaft or disk (not shown) is formed in the securing region 400.

15 The blade or vane root 183 is designed, for example, in hammerhead form. Other configurations, such as a fir-tree or dovetail root, are possible.

The blade or vane 120, 130 have a leading edge 409 and a trailing edge 412 for a medium which flows past the main
20 blade or vane part 406.

In the case of conventional blades or vanes 120, 130, by way of example solid metallic materials, in particular superalloys, are used in all regions 400, 403, 406 of the
25 blade or vane 120, 130.

Superalloys of this type are known, for example, from EP 1 204 776 B1, EP 1 306 454, EP 1 319 729 A1, WO 99/67435 or WO 00/44949; these documents form part of the disclosure
30 with regard to the chemical composition of the alloy.

The blade or vane 120, 130 may in this case be produced by a casting process, also by means of directional solidification, by a forging process, by a milling process or combinations thereof.

35

Work pieces with a single-crystal structure or structures are used as components for machines which, in operation, are exposed to high mechanical, thermal and/or chemical stresses.

Single-crystal work pieces of this type are produced, for example, by directional solidification from the melt. This involves casting processes in which the liquid metallic alloy solidifies to form the single-crystal structure, i.e. the single-crystal work piece, or solidifies directionally. In this case, dendritic crystals are oriented along the direction of heat flow and form either a columnar crystalline grain structure (i.e. grains which run over the entire length of the work piece and are referred to here, in accordance with the language customarily used, as directionally solidified) or a single-crystal structure, i.e. the entire work piece consists of one single crystal. In these processes, a transition to globular (polycrystalline) solidification needs to be avoided, since non-directional growth inevitably forms transverse and longitudinal grain boundaries, which negate the favorable properties of the directionally solidified or single-crystal component. Where the text refers in general terms to directionally solidified microstructures, this is to be understood as meaning both single crystals, which do not have any grain boundaries or at most have small-angle grain boundaries, and columnar crystal structures, which do have grain boundaries running in the longitudinal direction but do not have any transverse grain boundaries. This second form of crystalline structures is also described as directionally solidified microstructures (directionally solidified structures). Processes of this type are known from US 6,024,792 and EP 0 892 090 A1; these documents form part of the disclosure with regard to the solidification process.

The blades or vanes 120, 130 may likewise have coatings protecting against corrosion or oxidation, e.g. MCrAlX (M is at least one element selected from the group consisting of iron (Fe), cobalt (Co), nickel (Ni), X is an active element and represents yttrium (Y) and/or silicon and/or at least one rare earth element, or hafnium (Hf)). Alloys of this type are known from EP 0 486 489 B1, EP 0 786 017 B1, EP 0 412 397 B1 or EP 1 306 454 A1, which are intended to form part of the

present disclosure with regard to the chemical composition of the alloy.

The density is preferably 95% of the theoretical density.

A protective aluminum oxide layer (TGO = thermally grown
5 oxide layer) forms on the MCrAlX layer (as an intermediate layer or an outermost layer).

It is also possible for a thermal barrier coating, consisting
for example of ZrO_2 , Y_2O_3 - ZrO_2 , i.e. unstabilized, partially
10 stabilized or fully stabilized by yttrium oxide and/or calcium oxide and/or magnesium oxide, which is preferably the outermost layer, to be present on the MCrAlX.

The thermal barrier coating covers the entire MCrAlX layer. Columnar grains are produced in the thermal barrier coating
15 by means of suitable coating processes, such as for example electron beam physical vapor deposition (EB-PVD).

Other coating processes are conceivable, for example atmospheric plasma spraying (APS), LPPS, VPS or CVD. The thermal barrier coating may include porous grains which have
20 micro cracks or macro cracks for improving its resistance to thermal shocks. The thermal barrier coating is therefore preferably more porous than the MCrAlX layer.

The blade or vane 120, 130 may be hollow or solid in form. If
25 the blade or vane 120, 130 is to be cooled, it is hollow and may also have film-cooling holes 418 (indicated by dashed lines).

Patent claims

1. MCrAlY alloy
5 wherein M is Fe, Ni, Co,
especially M = Fe,
which comprises (in wt%)
18% - 35% chromium (Cr),
3% - 15% aluminum (Al),
10 0,2% - 2% yttrium (Y) and
78,8% to 39% iron (Fe)
and optionally
up to 3% titanium (Ti),
up to 3% hafnium (Hf),
15 up to 3% silicon (Si).
2. MCrAlY alloy according to claim 1,
which contains titanium (Ti).
20
3. MCrAlY alloy according to claim 1 or 2,
which contains hafnium (Hf).
25
4. MCrAlY alloy according to claim 1, 2 or 3,
which contains silicon (Si).
- 30 5. MCrAlY alloy according to claim 1, 2, 3 or 4,
which consists of M,
especially iron (Fe),
chromium (Cr), aluminum (Al) and Yttrium (Y) and optionally
titanium (Ti), hafnium (Hf) and silicon (Si).
35

6. MCrAlY alloy according to claim 1,
which consists of M,
especially iron (Fe),
chromium (Cr), aluminum (Al) and Yttrium (Y).

5

7. Method to form a diffusion area (8) inside a M-based
metallic material (10),
which comprises the metal M and optionally other base
elements,
wherein the diffusion area (8) comprises the composition
MCrAlY,
wherein M is Ni, Co or Fe,
especially according to one of the claims 1 to 6,
and wherein the diffusion area (8) is obtained by exposing
the M-based metallic material (10) with at least one of the
alloying elements Cr, Al, Y of this MCrAlY composition.

8. Method to produce a coating (7) on a honeycomb cell
(13),
wherein the honeycomb cell (13) is coated with the elements
of a MCrAlY alloy,
especially by a MCrAlY alloy according to claims 1, 2, 3,
4, 5 or 6.

9. Method according to claim 7,
wherein an honeycomb cell (13) comprises the M-based
metallic material,
especially consists of the M-based metallic material.

10. Method according to claim 7 or 8,
wherein the coating process or exposure process is a vapour
process,
especially a CVD process.

11. Method according to claim 7, 8 or 9,
wherein the coating (7) is applied on the honeycomb cells
(13) or the diffusion area (8) is produced
5 when the honeycomb cells (13) are already brazed onto a
substrate (4).

12. Method according to claim 7 or 8,
wherein the brazing is performed during coating or
10 exposing.

13. Method according to claim 7,
wherein the alloying elements Cr, Al, Y are coated
15 separately.

14. Method according to claim 7,
wherein at least two alloying elements of the elements Cr,
20 Al, Y are coated together.

15. Method according to claim 7, 8, 13 or 14,
wherein Hafnium (Hf), silicon (Si) or Titanium (Ti) is
25 coated or
diffused into the diffusion area (8).

16. Method according to claim 7,
30 wherein first chromium (Cr) is coated.

17. Method according to claim 7 or 8,
wherein M is only Fe.
35

18. Method according to claim 7,
wherein most of a thin wall (10) is diffused with the
5 alloying elements,
preferably the whole wall (10) is diffused throughout.

19. Honeycomb seal (1)
10 comprising
a substrate (4),
honeycomb cells (13),
a protective coating (7) on side walls (10) of the
honeycomb cells (13) or
15 a diffusion area (8) inside side walls (10) of the
honeycomb cells (13)
made of a MCrAlY alloy according to one or several of the
claims 1 to 6,
especially a FeCrAlY alloy
20 especially produced by a method according to claims 7 to
18.

20. Honeycomb seal according to claim 19,
25 wherein the side walls (10) of the honeycomb cells (13) are
made of steel or stainless steel.

21. Honeycomb seal according to claim 19 or 20
30 wherein the side wall (10) of the honeycomb cells (13)
comprises a diffusion area (8) of a MCrAlY alloy.

22. Honeycomb seal according to claim 19, 20 or 21,
35 wherein the MCrAlY coating (7) is on the braze,
which was used to join the honeycomb cells (13) and the
substrate (4) of the honeycomb seal (1).

23. Honeycomb cell according to claim 19, 20, 21, or 22,
wherein the sidewall (10) consists of a diffusion area (8).

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FIG 1

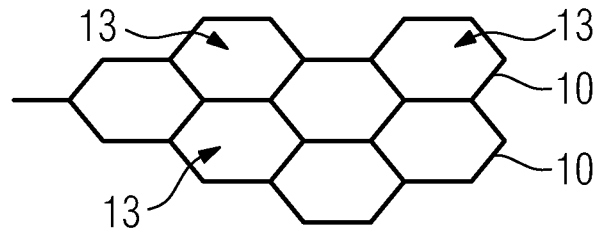


FIG 2

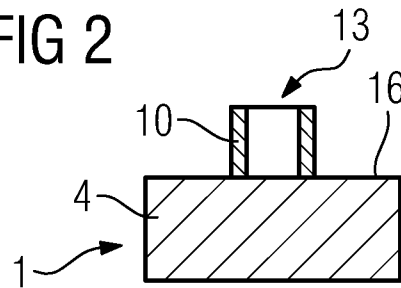


FIG 3

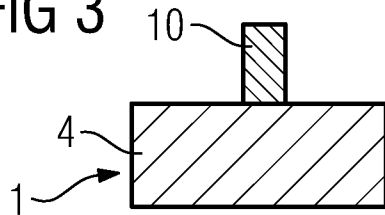


FIG 4

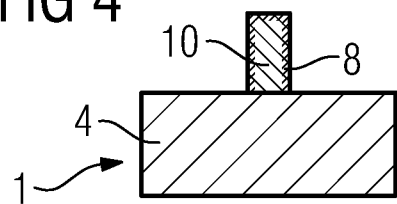


FIG 5

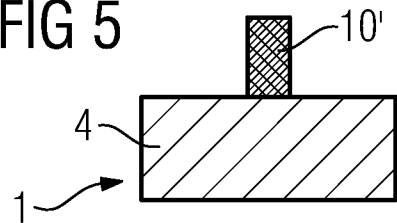


FIG 6

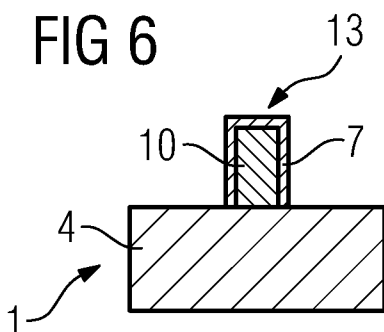


FIG 7

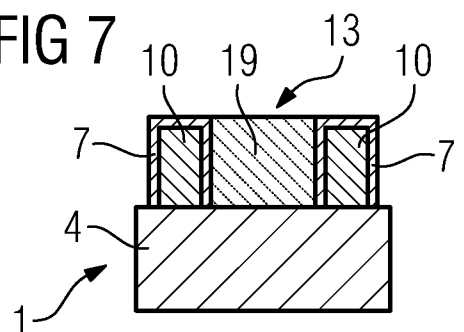


FIG 8

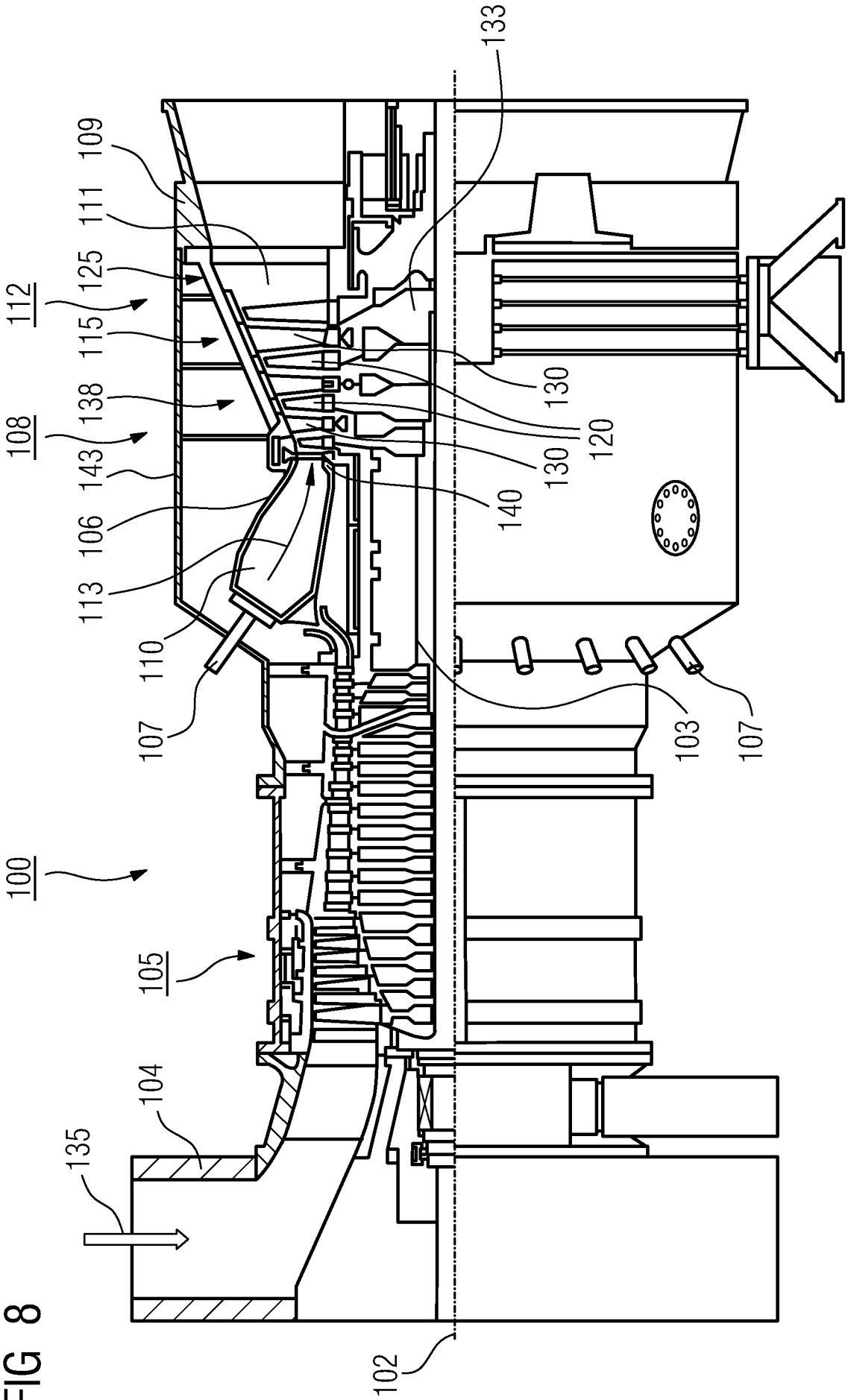
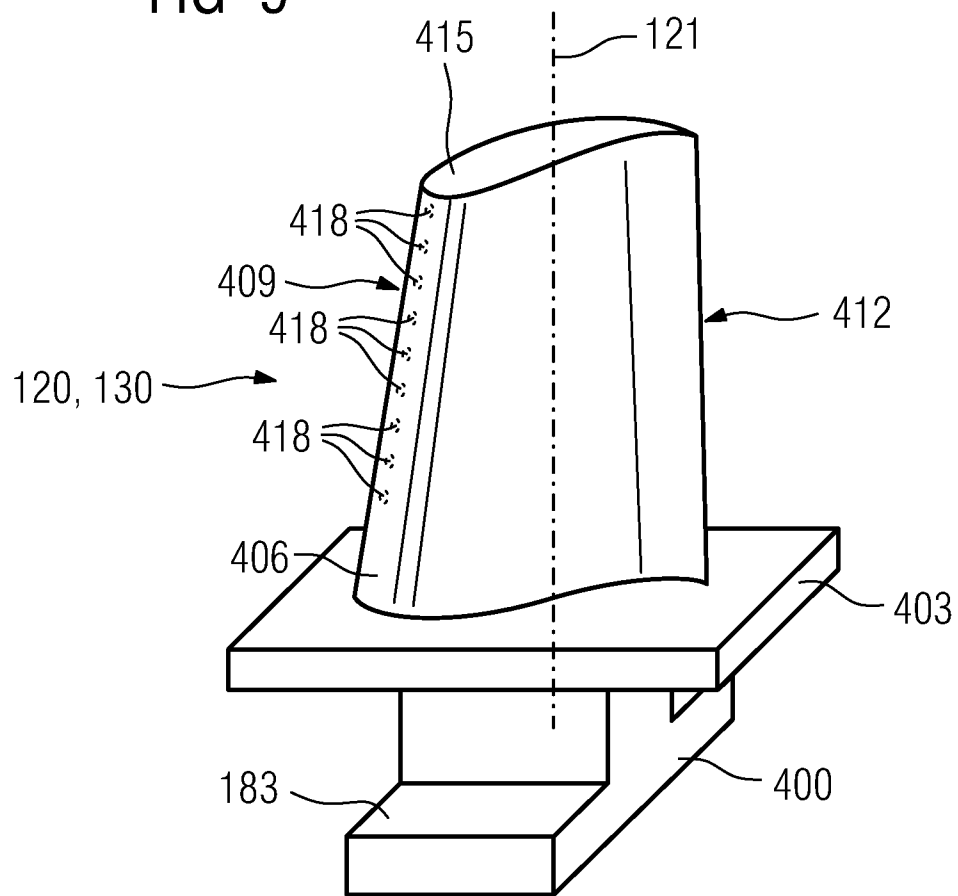


FIG 9



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/050743

A. CLASSIFICATION OF SUBJECT MATTER

INV. C23C4/08 C23C4/18 C23C10/02 C23C10/06 C23C10/08
C23C10/10 C23C10/12 C23C10/14 C23C10/56 C23C10/60

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C23C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 02/42610 A (WESTAIM CORP [CA]; HAMMERSLEY RICHARD CHARLES [GB]; SPORER DIETER RUDO) 30 May 2002 (2002-05-30)	1-6
A	claim 4	11, 12
X	US 3 542 530 A (TALBOOM FRANK P JR ET AL) 24 November 1970 (1970-11-24)	1, 5-7, 10, 14
Y	the whole document	13, 15, 16
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Date of the actual completion of the international search

4 March 2009

Date of mailing of the international search report

11/03/2009

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