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(54) **SINGLE CRYSTAL VANE SEGMENT AND METHOD OF MANUFACTURE**

EINKRISTALL-LEITSCHAUFEL UND VERFAHREN ZU DEREN HERSTELLUNG

SEGMENT D'AUBE A STRUCTURE MONOCRISTALLINE ET FABRICATION

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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates generally to cast gas turbine engine components and their method of manufacture. More particularly, in one embodiment of the present invention, a multi-airfoil vane segment is produced as a single crystal casting from a Rhenium containing directionally solidified (DS) chemistry alloy. Although the invention was developed for gas turbine engine components, certain applications may be outside of this field.

[0002] The performance of a gas turbine engine generally increases with an increase in the operating temperature of a high temperature working fluid flowing from a combustion chamber. One factor recognized by gas turbine engine designers as limiting the allowable temperature of the working fluid is the capability of the engine components to not degrade when exposed to the high temperature working fluid. The airfoils, such as blades and vanes, within the engine are among the components exposed to significant thermal and kinetic loading during engine operation.

[0003] Many gas turbine engines utilize cast components formed of a nickel or cobalt alloy. The components can be cast as a polycrystalline, directionally solidified, or single crystal structure. Generally, the most desirable material properties are associated with the single crystal structure. However, the geometry of some components, such as the multi-airfoil vane segment, causes difficulty during the casting process largely association with grain or crystal defects. Single crystal alloys are not tolerant to these types of defects and therefore castings, which exhibit these defects, are generally not suitable for engine use. Thus, the casting yields are lower and consequently the cost to manufacture the component increases.

[0004] Examples of components manufactured from such single crystal alloys are disclosed in French Patent No. FR-A-2 724 857 and US Patent No. 4,804,311.

[0005] A directionally solidified component has material properties between single crystal and polycrystalline and are easier to produce than single crystal components. Directionally solidified components are generally defined as multi-crystal structure with columnar grains and are generally cast from a directionally solidified alloy containing grain boundary strengtheners. The directionally solidified component is best suited for designs where the stress field is oriented along the columnar grains and the stress field transverse to the columnar grain is minimized. However, in a component, such as a multi-airfoil vane segment, the stress fields are elevated along the airfoils and in a transverse direction associated the inner and outer shrouds which tie the airfoils together.

[0006] An example of the use of a multi-crystal directionally solidified alloy in manufacture of a gas turbine engine blade is disclosed in US Patent 5,611,670. This describes a turbine engine blade having a conventional single crystal blade portion but with the remainder of the blade having a unidirectional solidified columnar grain structure.

[0007] Although the prior techniques can produce single crystal multi-airfoil vane segments, there remains a need for an improved single crystal multi-airfoil vane segment and method of manufacture. The present invention satisfies this and other needs in a novel and obvious way.

[0008] According to a first aspect of the present invention there is provided a vane segment component comprising a single cast single crystal structure formed of a directional solidified alloy type material, said single crystal structure has a plurality of airfoils integrally connected between a first endwall member and a second endwall member, said single crystal structure has its <001> crystal direction substantially parallel with a tangent to one of said endwall members and its <010> crystal direction substantially parallel with an average airfoil stacking axis.

[0009] According to a second aspect of the present invention there is provided a gas turbine engine component, comprising an integrally cast single crystal vane segment including a plurality of vanes, each of said plurality of vanes including a leading edge and a trailing edge and a first end and a second end, said vane segment has a first endwall member integrally connected with each of said first ends and a second endwall member integrally connected with each of said second ends, said vane segment formed of a directionally solidified alloy type material and having its <001> crystal direction substantially parallel with a tangent to one of said endwall members and its <010> crystal direction substantially parallel with an average airfoil stacking axis.

[0010] According to a third aspect of the present invention there is provided a method for producing a single crystal vane segment, comprising:

- providing a directionally solidified type alloy material;
- melting the directionally solidified type alloy material;
- pouring the molten directionally solidified type alloy material into a casting mold, the casting mold including an endwall forming cavity and a vane forming cavity defining a plurality of vanes that are in fluid communication;
- aligning a starter seed such that its <001> crystal direction is substantially parallel with a tangent to the vane segment and the starter seeds <010> crystal direction is substantially parallel with an average airfoil stacking axis;
- filling the endwall forming cavity and the vane forming cavity with the molten directionally solidified type alloy material;
- melting a portion of the starter seed extending into the the casting mold with the molten directionally solidified type

alloy material and

solidifying the directionally solidified alloy type material to produce an integrally cast vane segment having a structure consistent with a single crystal casting with its <001> crystal direction substantially parallel with a tangent to one of said endwall members and its <010> crystal direction substantially parallel with an average airfoil stacking axis.

[0011] Related objects and advantages of the present invention will be apparent from the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

FIG. 1 is an illustrative view of a gas turbine engine.

FIG. 2 is a perspective view of a multi-airfoil vane segment comprising a portion of the FIG. 1 gas turbine engine.

FIG. 3 is a Larson-Miller plot comparing three alloys.

FIG. 4 is an illustrative view of a casting mold for forming a vane segment.

FIG. 5 is an illustrative view of a multi-airfoil vane segment formed from the casting mold of FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0013] For the purposes of promoting an understanding of the principles of the invention, reference will now be made to the embodiment illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended, such alterations and further modifications in the illustrated device, and such further applications of the principles of the invention as illustrated therein being contemplated as would normally occur to one skilled in the art to which the invention relates.

[0014] Referring to FIG. 1, there is illustrated a gas turbine engine 20 which includes a fan section 21, a compressor section 22, a combustor section 23, and a turbine section 24 that are integrated together to produce an aircraft flight propulsion engine. This type of gas turbine engine is generally referred to as a turbo-fan. One alternate form of a gas turbine engine includes a compressor, a combustor, and a turbine that have been integrated together to produce an aircraft flight propulsion engine without the fan section. The term aircraft is generic and includes helicopters, airplanes, missiles, unmanned space devices and any other substantially similar devices. It is important to realize that there are a multitude of ways in which the gas turbine engine components can be linked together. Additional compressors and turbines could be added with intercoolers connecting between the compressors and reheat combustion chambers could be added between the turbines.

[0015] A gas turbine engine is equally suited to be used for an industrial application. Historically, there has been widespread application of industrial gas turbine engines, such as pumping sets for gas and oil transmission lines, electricity generation, and naval propulsion.

[0016] The compressor section 22 includes a rotor 25 having a plurality of compressor blades 26 coupled thereto. The rotor 25 is affixed to a shaft 27 that is rotatable within the gas turbine engine 20. A plurality of compressor vanes 28 are positioned within the compressor section 22 to direct the fluid flow relative to blades 26. Turbine section 24 includes a plurality of turbine blades 30 that are coupled to a rotor disk 31. The rotor disk 31 is affixed to the shaft 27, which is rotatable within the gas turbine engine 20. Energy extracted in the turbine section 24 from the hot gas exiting the combustor section 23 is transmitted through shaft 27 to drive the compressor section 22. Further, a plurality of turbine vanes 32 are positioned within the turbine section 24 to direct the hot gaseous flow stream exiting the combustor section 23.

[0017] The turbine section 24 provides power to a fan shaft 33, which drives the fan section 21. The fan section 21 includes a fan 34 having a plurality of fan blades 35. Air enters the gas turbine engine 20 in the direction of arrows A and passes through the fan section 21 into the compressor section 22 and a bypass duct 36. Further details related to the principles and components of a conventional gas turbine engine will not be described herein as they are believed known to one of ordinary skill in the art.

[0018] With reference to FIG. 2, there is illustrated a vane segment 50 which forms a portion of a turbine nozzle. A plurality of vane segments 50 are conventionally joined together to collectively form the complete 360° turbine nozzle. Each of the vane segments 50 include a plurality of vanes 32 that are coupled to end wall members 51 and 52. The embodiment of vane segment 50, illustrated in FIG. 2, has four vanes coupled thereto, however it is contemplated herein that a vane segment may have one or more vanes per vane segment and is not limited to a vane segment having four vanes. In a preferred form of the present invention the turbine nozzle includes eleven vane segments having four vanes each. However, a turbine nozzle formed from other quantities of vane segments, and vane segments having other numbers of vanes are contemplated herein.

[0019] Vane 32 has a leading edge 32a and a trailing edge 32b and an outer surface extending therebetween. The term spanwise will be used herein to indicate an orientation between the first end wall member 51 and the second end

wall member 52. Further, the term streamwise will be used herein to indicate an orientation between the leading edge 32a and the trailing edge 32b. Each vane 50 defines an airfoil with the outer surface 53 extending between the leading edge 32a and the trailing edge 32b. The leading and trailing edges of the vane extend between a first end 32c and a second opposite other end 32d. The outer surface 53 of the vane 50 includes a convex suction side (not illustrated) and a concave pressure side 55.

[0020] In one embodiment, the gas turbine engine vane 32 is a hollow single-cast single crystal structure produced by single crystal casting techniques utilizing a directionally solidified alloy composition. In another embodiment, the gas turbine engine vane is a solid single-cast single crystal structure produced by single crystal casting techniques utilizing a directionally solidified alloy composition. Further, the present invention contemplates gas turbine engine vanes having internal cooling passageways and apertures for the passage of a cooling media. Cast single crystal casting techniques are believed known to those of ordinary skill in the art. One process for producing a cast single crystal structure is set forth in United States Patent No. 5,295,530 to O'Connor, which is incorporated herein by reference.

[0021] In the present invention the material utilized to produce the cast single crystal structure is a directionally solidified alloy, which often is referred to as a DS alloy. More preferably, the alloy is a second-generation directionally solidified superalloy. Second-generation directionally solidified superalloys have creep rupture strengths similar to first generation single crystal superalloys, such as CMSX-2[®] and CMSX-3[®] at up to 1000 degrees centigrade. For example in Fig. 3, there is illustrated a Larson-Miller Plot showing the strength of CM 186 LC in comparison to CMSX 2/3 and CM247LC. Examples of the second-generation superalloys include, but are not intended to be limited herein to: PWA 1426 (a Pratt & Whitney product); René 142 (a General Electric product); and, CM186 LC (a Cannon -Muskegon product). Other directionally solidified alloys are contemplated herein for use in producing a cast single crystal structure.

[0022] Each of the directionally solidified alloys include grain boundary strengtheners that are designed to increase grain boundary strength. The alloys PWA 1426, Rene 142 and CM186 LC each include boron, carbon, hafnium, and zirconium as their grain boundary strengtheners. Other directionally solidified alloys containing grain boundary strengtheners are contemplated herein. A grain boundary is generally defined as a region in the cast component of non-oriented structure having a width of only a few atomic diameters which serves to accommodate the crystallographic orientation difference or mismatch between adjacent grains. It will be appreciated by those skilled in the art that neither low angle grain boundaries nor high angle grain boundaries will be present in a theoretical "single crystal". However, it will be further appreciated that although there may be one or more grain boundaries present in commercial single crystal structures, they are still characterized as a single crystal structure. Further, manufacturing processes more tolerant of these crystal anomalies are inherently less expensive.

[0023] The nominal chemical composition for the Rhenium containing alloys PWA 1426, Rene 142 and CM186 LC are disclosed in Table I.

TABLE I.

NOMINAL COMPOSITION, WEIGHT %														
Alloy	Cr	Co	Mo	W	Ta	Re	Al	Ti	Hf	C	B	Zr	Ni	Density (kg/dm)
PWA 1426	6.5	12	2	6	4	3	6.0	-	1.5	.10	.015	.03	BAL	8.6
René 142	6.8	12	2	5	6	3	6.2	-	1.5	.12	.015	.02	BAL	8.6
CM 186 LC	6.0	9	.5	8	3	3	5.7	.7	1.4	.07	.015	.005	BAL	8.70

[0024] With reference to FIG. 4, there is illustrated a casting mold 200 with a molten metal receiving cavity for receiving molten metal therein and forming the multi-airfoil vane segment. Referring to FIG. 5, there is illustrated the multi-airfoil vane segment 50 and metallic starter seed 62 with the walls of a casting mold 200 removed to aid the reader. A portion of the metallic starter seed 62 extends into the molten metal receiving cavity of the mold. The molten directionally solidified alloy contacts the starter seed 62 and causes the partial melt back thereof. In a preferred form of the process for producing the cast multi-airfoil vane segment the starter seed 62 is not in contact with a chill 65. More preferably an insulator 90 is disposed between the starter seed 62 and the chill 65. The insulator 90 functions to thermally insulate the starter seed 62 from the cooling chill 65 and thus promote melting of a portion of the starter seed.

[0025] The directionally solidified alloy is solidified by a thermal gradient moving vertically through the casting mold. More particularly, the directionally solidified alloy is solidified epitaxially from the unmelted portion of the starter seed 62

to form the single crystal product. In one form, the thermal gradient for solidifying the directionally solidified alloy is produced by a combination of mold heating and mold cooling. One system for effectuating the thermal gradient in the mold comprises a mold heater, a mold cooling cone, a chill and the withdrawal of the structure being cast. Further details related to the growing of single crystal alloy structures are believed known to those of ordinary skill in the art and therefore have not been provided. The cast single crystal alloy product has been described in terms of a vane segment, however other cast single crystal product configurations formed of a directionally solidified alloy, such as blades seals, shrouds, blade tracks, nozzle liners and other components subjected to high temperature and stress are contemplated herein.

[0026] In one form of the present invention the starter seed 62 is formed and/or oriented such that the seeds <001> (primary orientation) crystal direction is substantially parallel with a tangent A, and the seeds <010> (secondary orientation) crystal direction is substantially parallel with the average airfoil stacking axis B. The average airfoil stacking axis B is generally defined by the average of each airfoil stacking axis B₁, B₂, B₃, and B₄. The illustration of FIG. 5 is not intended herein to limit the solidification direction to that shown in the drawings. In an alternative embodiment the solidification direction is substantially parallel to the average airfoil stacking axis B. Further, other solidification directions are contemplated herein. The present invention is not limited to the use of a starter seed to impart the crystallographic structure to the crystal being grown. Single crystals can be grown by techniques generally known to one of ordinary skill in the art, such as utilizing thermal nucleation and the selection of a grain for continued growth with a pigtail sorting structure.

[0027] In one form the cast single crystal vane segment can be used without the long homogenization heat treat cycles commonly used to maximize properties of cast single crystal articles. In another form of the present invention, which is well suited for articles such as gas turbine blades, the article can be used in a fully heat treated condition. The fully heat treated article maximizes stress rupture and minimizes the formation of deleterious topologically close packed (TCP) phases such as sigma upon the long term exposure of the article to high temperature and stress. The long term exposure will be greater than one thousand hours.

[0028] While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only the preferred embodiment has been shown and described and that all changes and modifications that come within the spirit of the invention are desired to be protected.

Claims

1. A vane segment component comprising a cast single crystal structure formed of a directional solidified alloy type material, said single crystal structure has a plurality of airfoils integrally connected between a first endwall member and a second endwall member, said single crystal structure has its <001> crystal direction substantially parallel with a tangent to one of said endwall members and its <010> crystal direction substantially parallel with an average airfoil stacking axis.
2. A gas turbine engine component, comprising an integrally cast single crystal vane segment including a plurality of vanes, each of said plurality of vanes including a leading edge and a trailing edge and a first end and a second end, said vane segment has a first endwall member integrally connected with each of said first ends and a second endwall member integrally connected with each of said second ends, said vane segment formed of a directionally solidified alloy type material and having its <001> crystal direction substantially parallel with a tangent to one of said endwall members and its <010> crystal direction substantially parallel with an average airfoil stacking axis.
3. The component of any of claims 1 or 2, wherein said directionally solidified alloy type material includes Rhenium.
4. The component of claim 3, wherein said directionally solidified alloy type material includes about 3 weight percent Rhenium.
5. The component of any of claims 1 or 2, wherein said alloy consisting essentially of, in percentages by weight, 0.07 C, 6 Cr, 9 Co, 0.5 Mo, 8 W, 3 Ta, 3 Re, 5.7 Al, 0.7 Ti, 0.015 B, 0.005 Zr, 1.4 Hf, the balance being nickel and incidental impurities.
6. The component of any of claims 1 or 2, wherein said alloy consisting essentially of, in percentages by weight, 6.8 Cr, 12 Co, 2 Mo, 5 W, 6 Ta, 3 Re, 6.2 Al, 1.5 Hf, .12 C, .015 B, .02 Zr, the balance being nickel and incidental impurities.
7. The component of any of claims 1 or 2, wherein said alloy consisting essentially of, in percentages by weight, 6.5 Cr, 12 Co, 2 Mo, 6 W, 4 Ta, 3 Re, 1.5 Hf, .10 C, .015 B, .03 Zr, 6.0 Al, the balance being nickel and incidental impurities.

8. The component of any preceeding claim, wherein at least one of said plurality of vanes has an internal cooling passageway for the passage of a cooling media.

9. A method for producing a single crystal vane segment, comprising:

providing a directionally solidified type alloy material;
melting the directionally solidified type alloy material;
pouring the molten directionally solidified type alloy material into a casting mold, the casting mold including an endwall forming cavity and a vane forming cavity defining a plurality of vanes that are in fluid communication;
aligning a starter seed such that its <001> crystal direction is substantially parallel with a tangent to the vane segment and the starter seeds <010> crystal direction is substantially parallel with an average airfoil stacking axis;
filling the endwall forming cavity and the vane forming cavity with the molten directionally solidified type alloy material;
melting a portion of the starter seed extending into the casting mold with the molten directionally solidified type alloy material; and
solidifying the directionally solidified alloy type material to produce an integrally cast vane segment having a structure consistent with a single crystal casting with its <001> crystal direction substantially parallel with a tangent to one of said endwall members and its <010> crystal direction substantially parallel with an average airfoil stacking axis.

10. The method of claim 9, which further includes providing a metallic starter seed that does not remain coupled with the produced integrally cast vane segment, and wherein a portion of the metallic starter seed is positioned within the casting mold and receives molten directionally solidified type alloy material thereon.

11. The method of claim 10, which further includes partially melting back the starter seed.

12. The method of claim 10 or 11, wherein in the solidifying the directionally solidified alloy is solidified epitaxially from an unmelted portion of the starter seed.

13. The method of any of claims 9 to 12, which further includes providing a chill to withdraw energy through said starter seed, and which further includes thermally insulating the starter seed from the chill to promote partially melting back the starter seed.

14. The method of any of claims 9 to 13, wherein said directionally solidified type alloy material is selected from the group consisting of:

- (a) an alloy consisting essentially of, in percentages by weight, 0.07 C, 6 Cr, 9 Co, 0.5 Mo, 8 W, 3 Ta, 3 Re, 5.7 Al, 0.7 Ti, 0.015 B, 0.005 Zr, 1.4 Hf, the balance being nickel and incidental impurities;
- (b) an alloy consisting essentially of, in percentages by weight, 6.8 Cr, 12 Co, 2 Mo, 5 W, 6 Ta, 3 Re, 6.2 Al, 1.5 Hf, .12 C, .015 B, .02 Zr, the balance being nickel and incidental impurities; and
- (c) an alloy consisting essentially of, in percentages by weight, 6.5 Cr, 12 Co, 2 Mo, 6 W, 4 Ta, 3 Re, 1.5 Hf, .10 C, .015 B, .03 Zr, 6.0 Al, the balance being nickel and incidental impurities.

Patentansprüche

1. Schaufelsegmentkomponente, die eine gegossene Einkristall-Gußstruktur umfasst, die aus einem gerichtet erstarrenden Legierungsmaterial geformt wird, wobei die Einkristallstruktur eine Vielzahl von Flügelprofilen aufweist, die einstückig zwischen einem ersten Stirnwandelement und einem zweiten Stirnwandelement verbunden sind, wobei die Einkristall-Gußstruktur ihre <001>-Kristallrichtung im Wesentlichen parallel zu einer Tangente zu einem der Stirnwandelemente hat und ihre <010>-Kristallrichtung im Wesentlichen parallel zu einer mittleren Flügelprofilstapelachse hat.
2. Gasturbinentriebwerkskomponente, die ein in einem Stück gegossenes Einkristallschaufelsegment mit mehreren Schaufeln umfasst, wobei jede der mehreren Schaufeln eine Vorderkante und eine Hinterkante sowie ein erstes Ende und ein zweites Ende enthält, wobei das Schaufelsegment ein erstes Stirnwandelement, das mit jedem der ersten Enden einstückig verbunden ist, und ein zweites Stirnwandelement aufweist, das mit jedem der zweiten Enden einstückig verbunden ist, wobei das Schaufelsegment aus einem gerichtet erstarrenden Legierungsmaterial

geformt wird und seine <001>-Kristallrichtung im Wesentlichen parallel zu einer Tangente zu einem der Stirnwandelemente hat und ihre <010>-Kristallrichtung im Wesentlichen parallel zu einer mittleren Flügelprofilstapelachse hat.

3. Komponente nach einem der Ansprüche 1 oder 2, wobei das gerichtet erstarrende Legierungsmaterial Rhenium enthält.

4. Komponente nach Anspruch 3, wobei das gerichtet erstarrende Legierungsmaterial etwa 3 Gew.-% Rhenium enthält.

5. Komponente nach einem der Ansprüche 1 oder 2, wobei die Legierung im Wesentlichen aus den folgenden Bestandteilen in Gew.-% besteht: 0,07 C, 6 Cr, 9 Co, 0,5 Mo, 8 W, 3 Ta, 3 Re, 5,7 Al, 0,7 Ti, 0,015 B, 0,005 Zr, 1,4 Hf, wobei der Rest aus Nickel und zufälligen Verunreinigungen besteht.

6. Komponente nach einem der Ansprüche 1 oder 2, wobei die Legierung im Wesentlichen aus den folgenden Bestandteilen in Gew.-% besteht: 6,8 Cr, 12 Co, 2 Mo, 5 W, 6 Ta, 3 Re, 6,2 Al, 1,5 Hf, 0,12 C, 0,015 B, 0,02 Zr, wobei der Rest aus Nickel und zufälligen Verunreinigungen besteht.

7. Komponente nach einem der Ansprüche 1 oder 2, wobei die Legierung im Wesentlichen aus den folgenden Bestandteilen in Gew.-% besteht: 6,5 Cr, 12 Co, 2 Mo, 6 W, 4 Ta, 3 Re, 1,5 Hf, 0,10 C, 0,015 B, 0,03 Zr, 6,0 Al, wobei der Rest aus Nickel und zufälligen Verunreinigungen besteht.

8. Komponente nach einem der vorhergehenden Ansprüche, wobei mindestens eine von den mehreren Schaufeln einen inneren Kühlungskanal für den Durchfluss eines Kühlmittels aufweist.

9. Verfahren zur Herstellung eines Einkristallschaufelsegments, umfassend:

Bereitstellen eines gerichtet erstarrenden Legierungsmaterials;

Schmelzen des gerichtet erstarrenden Legierungsmaterials;

Gießen des gerichtet erstarrenden Legierungsmaterials in eine Gießform, wobei die Gießform einen stirnwandformenden Hohlraum und einen schaufelformenden Hohlraum, der eine Vielzahl von Schaufeln definiert, aufweist, die in Fluidverbindung stehen;

Ausrichten eines Starterkeimmaterials, so dass seine <001>-Kristallrichtung im Wesentlichen parallel zu einer Tangente zum Schaufelsegment ist und die <010>-Kristallrichtung des Starterkeimmaterials im Wesentlichen parallel zu einer mittleren Flügelprofilstapelachse ist;

Füllen des stirnwandformenden Hohlraums und des schaufelformenden Hohlraums mit dem geschmolzenen gerichtet erstarrenden Legierungsmaterial;

Schmelzen eines Abschnitts des Starterkeimmaterials, das sich mit dem geschmolzenen gerichtet erstarrenden Legierungsmaterial in die Gießform erstreckt; und

Erstarrenlassen des gerichtet erstarrenden Legierungsmaterials, um ein in einem Stück gegossenes Schaufelsegment mit einer Struktur herzustellen, die mit einem Einkristallgußstück übereinstimmt, dessen <001>-Kristallrichtung im Wesentlichen parallel zu einer Tangente zu einem der Stirnwandelemente ist und dessen <010>-Kristallrichtung im Wesentlichen parallel zu einer mittleren Flügelprofilstapelachse ist.

10. Verfahren nach Anspruch 9, das ferner die Bereitstellung eines metallischen Starterkeimmaterials aufweist, das nicht mit dem erzeugten, in einem Stück gegossenen Schaufelsegment verbunden bleibt, und wobei ein Abschnitt des metallischen Starterkeimmaterials innerhalb der Gießform angeordnet ist und geschmolzenes, gerichtet erstarrendes Legierungsmaterial darauf aufnimmt.

11. Verfahren nach Anspruch 10, das ferner das teilweise Rückschmelzen des Starterkeimmaterials enthält.

12. Verfahren nach Anspruch 10 oder Anspruch 11, wobei beim Erstarren die gerichtet erstarrende Legierung von einem nicht geschmolzenen Abschnitt des Starterkeimmaterials aus epitaxial erstarrt.

13. Verfahren nach einem der Ansprüche 9 bis 12, das ferner die Bereitstellung einer Abschreckschicht zum Entzug von Energie durch das Starterkeimmaterial hindurch enthält, und das ferner eine Wärmeisolierung des Starterkeimmaterials von der Abschreckschicht enthält, um das teilweise Rückschmelzen des Starterkeimmaterials zu fördern.

14. Verfahren nach einem der Ansprüche 9 bis 13, wobei das gerichtet erstarrende Legierungsmaterial aus der Gruppe ausgewählt ist, bestehend aus:

(a) einer Legierung, die im Wesentlichen aus den folgenden Bestandteilen in Gew.-% besteht: 0,07 C, 6 Cr, 9 Co, 0,5 Mo, 8 W, 3 Ta, 3 Re, 5,7 Al, 0,7 Ti, 0,015 B, 0,005 Zr, 1,4 Hf, wobei der Rest aus Nickel und zufälligen Verunreinigungen besteht;

(b) einer Legierung, die im Wesentlichen aus den folgenden Bestandteilen in Gew.-% besteht: 6,8 Cr, 12 Co, 2 Mo, 5 W, 6 Ta, 3 Re, 6,2 Al, 1,5 Hf, 0,12 C, 0,015 B, 0,02 Zr, wobei der Rest aus Nickel und zufälligen Verunreinigungen besteht; und

(c) einer Legierung, die im Wesentlichen aus den folgenden Bestandteilen in Gew.-% besteht: 6,5 Cr, 12 Co, 2 Mo, 6 W, 4 Ta, 3 Re, 1,5 Hf, 0,10 C, 0,015 B, 0,03 Zr, 6,0 Al, wobei der Rest aus Nickel und zufälligen Verunreinigungen besteht.

Revendications

1. Composant segmenté d'aube comprenant une structure monocristalline coulée formée d'un matériau du type alliage solidifié directionnel, ladite structure monocristalline possédant une pluralité de profils aérodynamiques reliés d'un seul tenant entre un premier élément de paroi d'extrémité et un second élément de paroi d'extrémité, la direction de cristal <001> de ladite structure monocristalline étant substantiellement parallèle à une tangente à un desdits éléments de paroi d'extrémité et sa direction de cristal <010> étant substantiellement parallèle à un axe d'empilement du profil aérodynamique moyen.

2. Composant de moteur à turbine à gaz, comprenant un segment d'aube monocristallin coulé d'un seul tenant comprenant une pluralité d'aubes, chaque aube de ladite pluralité d'aubes comprenant un bord d'attaque et un bord de fuite et une première extrémité et une seconde extrémité, ledit segment d'aube possédant un premier élément de paroi d'extrémité relié d'un seul tenant avec chacune desdites premières extrémités et un second élément de paroi d'extrémité relié d'un seul tenant avec chacune desdites secondes extrémités, ledit segment d'aube étant formé d'un matériau du type alliage à solidification directionnelle et sa direction de cristal <001> étant substantiellement parallèle à une tangente à un desdits éléments de paroi d'extrémité et sa direction de cristal <010> étant substantiellement parallèle à un axe d'empilement du profil aérodynamique moyen..

3. Composant d'une quelconque des revendications 1 ou 2, dans lequel ledit matériau en alliage du type à solidification directionnelle comprend du rhénium.

4. Composant de la revendication 3, dans lequel ledit matériau du type alliage à solidification directionnelle comprend environ 3 pour cent en poids de rhénium.

5. Composant d'une quelconque des revendications 1-2, dans lequel ledit alliage est composé essentiellement de, exprimé en pourcentages pondéraux, 0,07 C, 6 Cr, 9 Co, 0,5 Mo, 8 W, 3 Ta, 3 Re, 5,7 Al, 0,7 Ti, 0,015 B, 0,005 Zr, 1,4 Hf, le restant étant du nickel et des impuretés fortuites.

6. Composant d'une quelconque des revendications 1 ou 2, dans lequel ledit alliage est composé essentiellement de, exprimé en pourcentages pondéraux, 6,8 Cr, 12 Co, 2 Mo, 5 W, 6 Ta, 3 Re, 6,2 Al, 1,5 Hf, 0,12 C, 0,015 B, 0,02 Zr, le restant étant du nickel et des impuretés fortuites.

7. Composant d'une quelconque des revendications 1 ou 2, dans lequel ledit alliage est composé essentiellement de, exprimé en pourcentages pondéraux, 6,5 Cr, 12 Co, 2 Mo, 6 W, 4 Ta, 3 Re, 1,5 Hf, 0,10 C, 0,015 B, 0,03 Zr, 6,0 Al, le restant étant du nickel et des impuretés fortuites.

8. Composant d'une quelconque des revendications précédentes, dans lequel au moins une aube de ladite pluralité des aubes possède un passage de refroidissement interne pour le passage d'un milieu de refroidissement.

9. Procédé de production d'un segment d'aube monocristallin, consistant à:

prévoir un matériau en alliage du type à solidification directionnelle;

faire fondre le matériau en alliage du type à solidification directionnelle;

verser le matériau en alliage du type à solidification directionnelle fondu dans un moule de coulage, le moule de coulage comprenant une cavité formant une paroi d'extrémité et une cavité formant une aube définissant une pluralité d'aubes qui sont en communication de fluide;

aligner un ensemencement d'amorce de sorte que sa direction de cristal <001> est substantiellement parallèle

à une tangente au segment d'aube et la direction de cristal <010> de l'ensemencement d'amorce est substantiellement parallèle à un axe d'empilement du profil aérodynamique moyen ;
remplir la cavité formant la paroi d'extrémité et la cavité formant l'aube avec le matériau en alliage du type à solidification directionnelle fondu;

faire fondre une partie de l'ensemencement d'amorce s'étendant dans le moule de coulage avec le matériau en alliage du type à solidification directionnelle; et

solidifier le matériau en alliage de type à solidification directionnelle pour produire un segment d'aube coulé d'un seul tenant possédant une structure compatible avec une pièce coulée monocristalline, sa direction de cristal <000> étant substantiellement parallèle à une tangente à un desdits éléments de paroi d'extrémité et sa direction de cristal <010> étant substantiellement parallèle à un axe d'empilement du profil aérodynamique moyen.

10. Procédé de la revendication 9, qui comprend en outre la réalisation d'un ensemencement d'amorce métallique qui ne reste pas couplé avec le segment d'aube coulé d'un seul tenant produit, et dans lequel une partie de l'ensemencement d'amorce métallique est positionné à l'intérieur du moule de coulage et reçoit un matériau en alliage du type à solidification directionnelle fondu sur celui-ci.

11. Procédé de la revendication 10, qui comprend en outre la refonte partielle de l'ensemencement d'amorce.

12. Procédé de la revendication 10 ou de la revendication 11, dans lequel, lors de ladite solidification, l'alliage à solidification directionnelle se solidifie par épitaxie à partir de la partie non fondue de l'ensemencement d'amorce.

13. Procédé d'une quelconque des revendications 9 à 12, qui comprend en outre le fait de prévoir une coquille pour retirer de l'énergie à travers ledit ensemencement d'amorce, et qui comprend en outre l'isolation thermique de l'ensemencement d'amorce de la coquille pour promouvoir la refonte partielle de l'ensemencement d'amorce.

14. Procédé d'une quelconque des revendications 9 à 13, dans lequel ledit matériau en alliage du type à solidification directionnelle est sélectionné dans le groupe constitué de :

(a) un alliage constitué essentiellement, exprimé en pourcentages pondéraux, de 0,07 C, 6 Cr, 9 Co, 0,5 Mo, 8 W, 3 Ta, 3 Re, 5,7 Al, 0,7 Ti, 0,015 B, 0,005 Zr, 1,4 Hf, le reste étant du nickel et des impuretés fortuites.

(b) un alliage constitué essentiellement, exprimé en pourcentages pondéraux, de 6,8 Cr, 12 Co, 2 Mo, 5 W, 6 Ta, 3 Re, 6,2 Al, 1,5 Hf, 0,12 C, 0,015 B, 0,02 Zr, le reste étant du nickel et des impuretés fortuites.

(c) un alliage constitué essentiellement, exprimé en pourcentages pondéraux, de 6,5 Cr, 12 Co, 2 Mo, 6 W, 4 Ta, 3 Re, 1,5 Hf, 0,10 C, 0,015 B, 0,03 Zr, 6,0 Al, le reste étant du nickel et des impuretés fortuites.

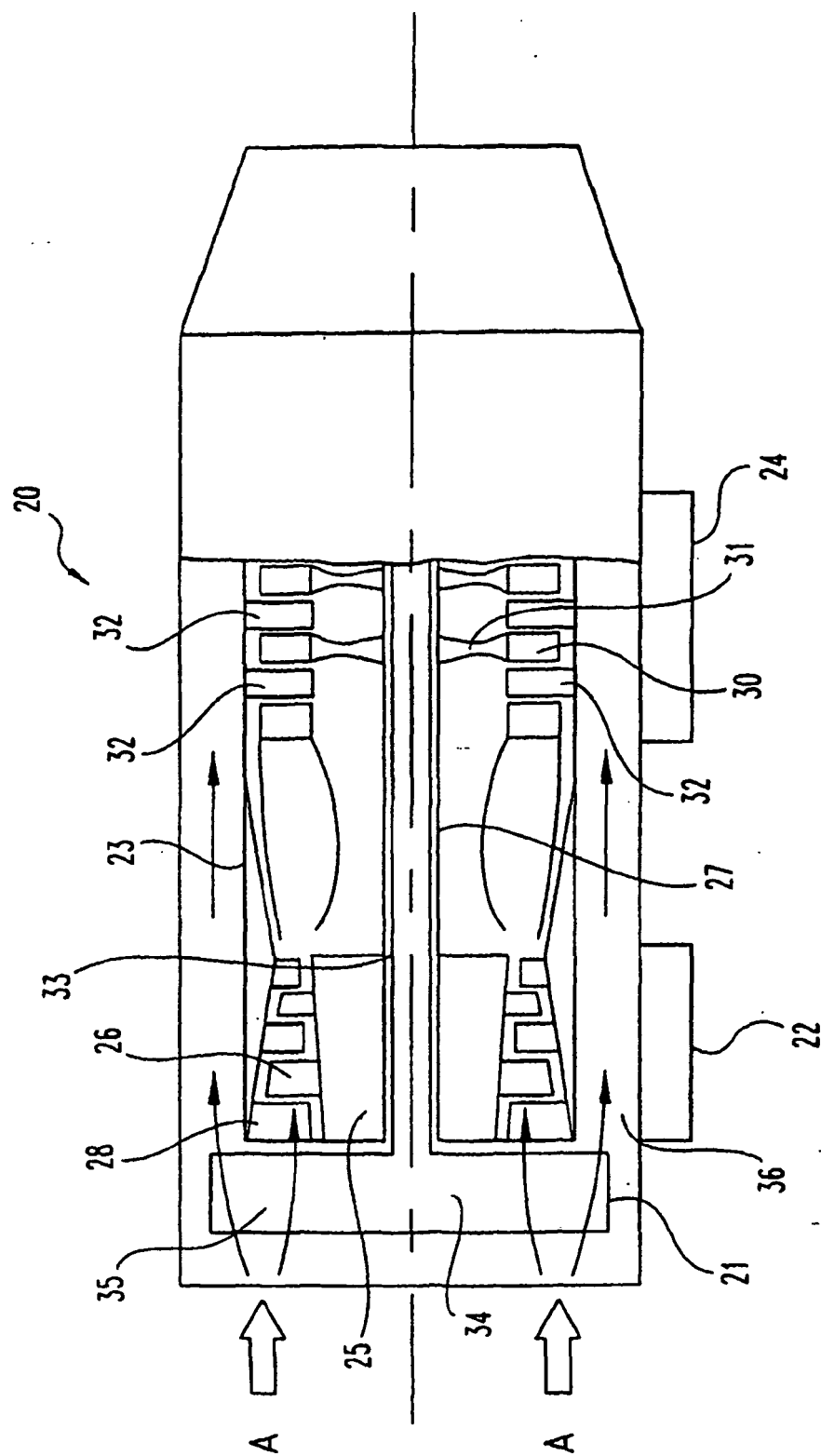


Fig. 1

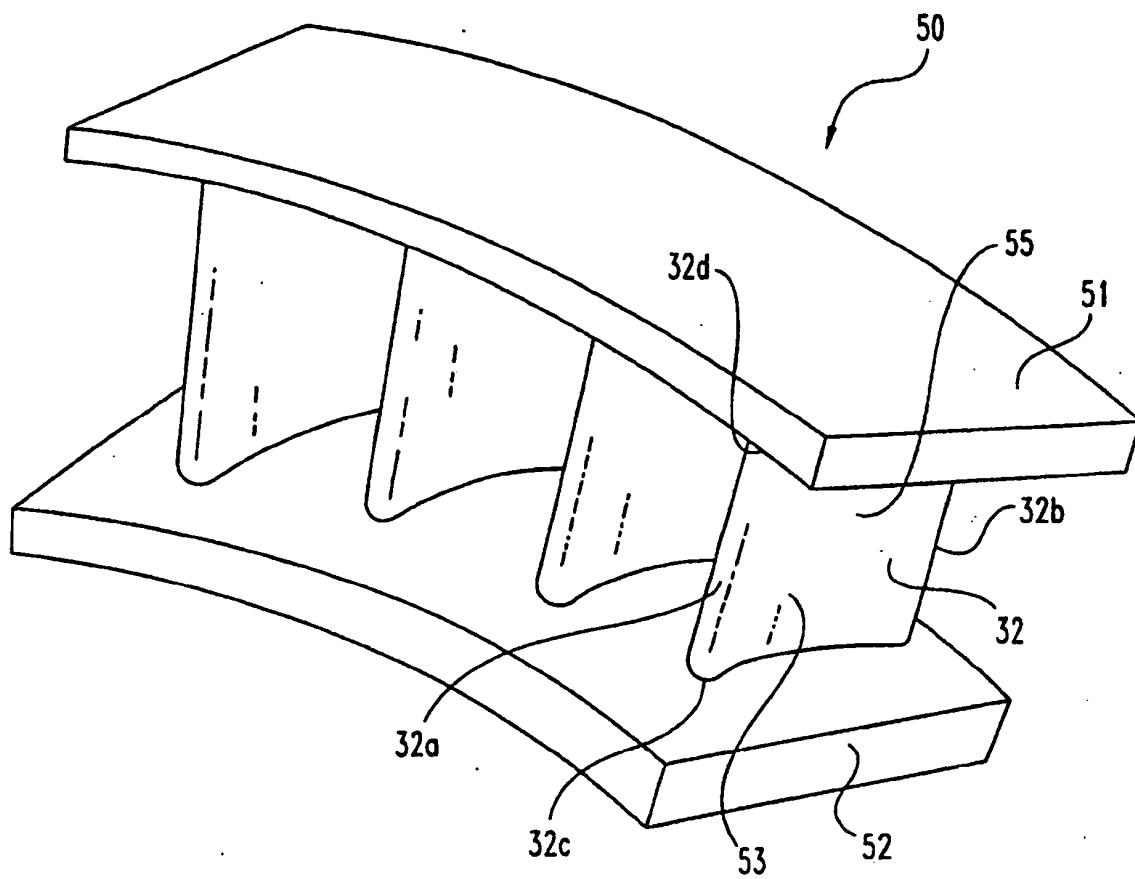
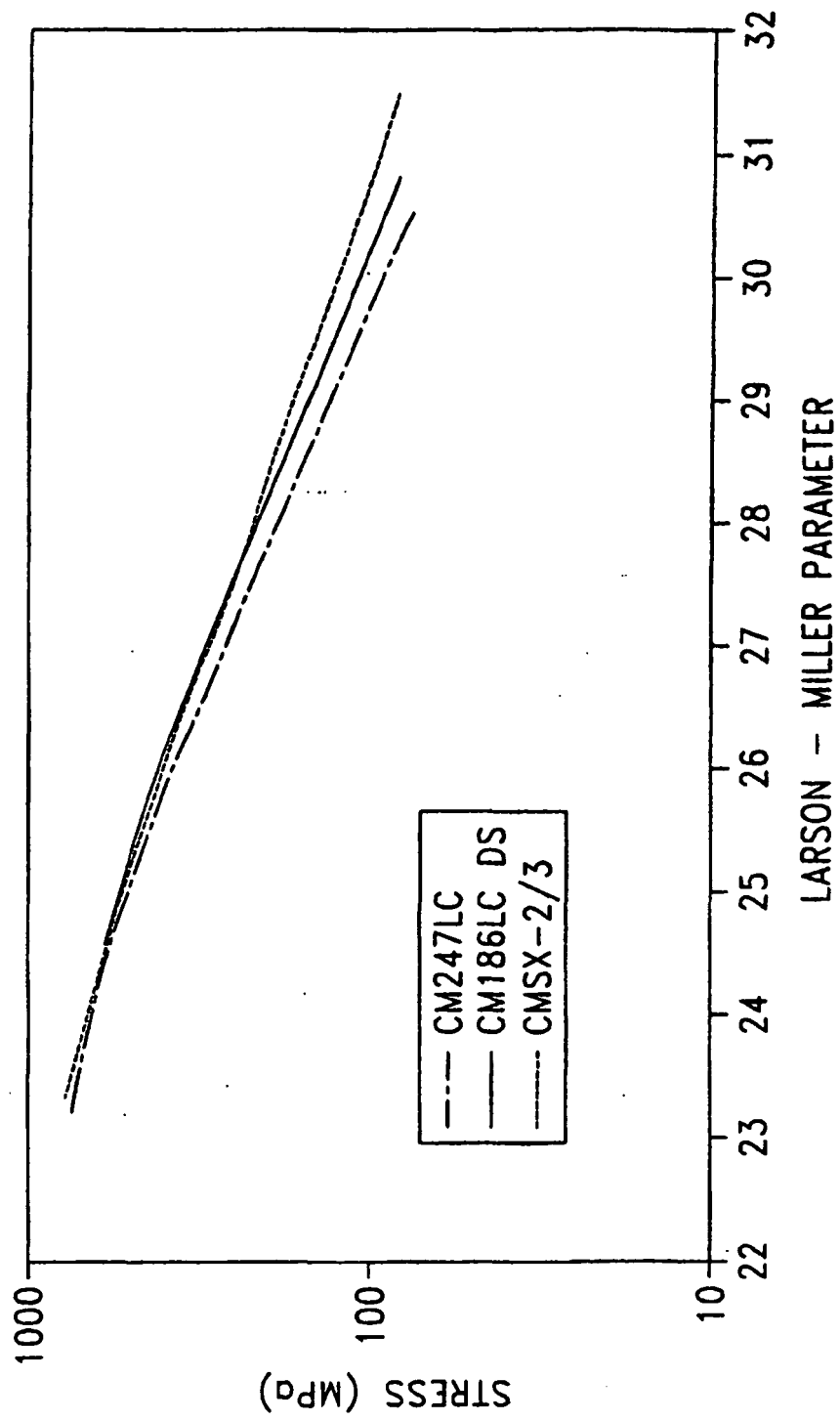


Fig. 2

**Fig. 3**

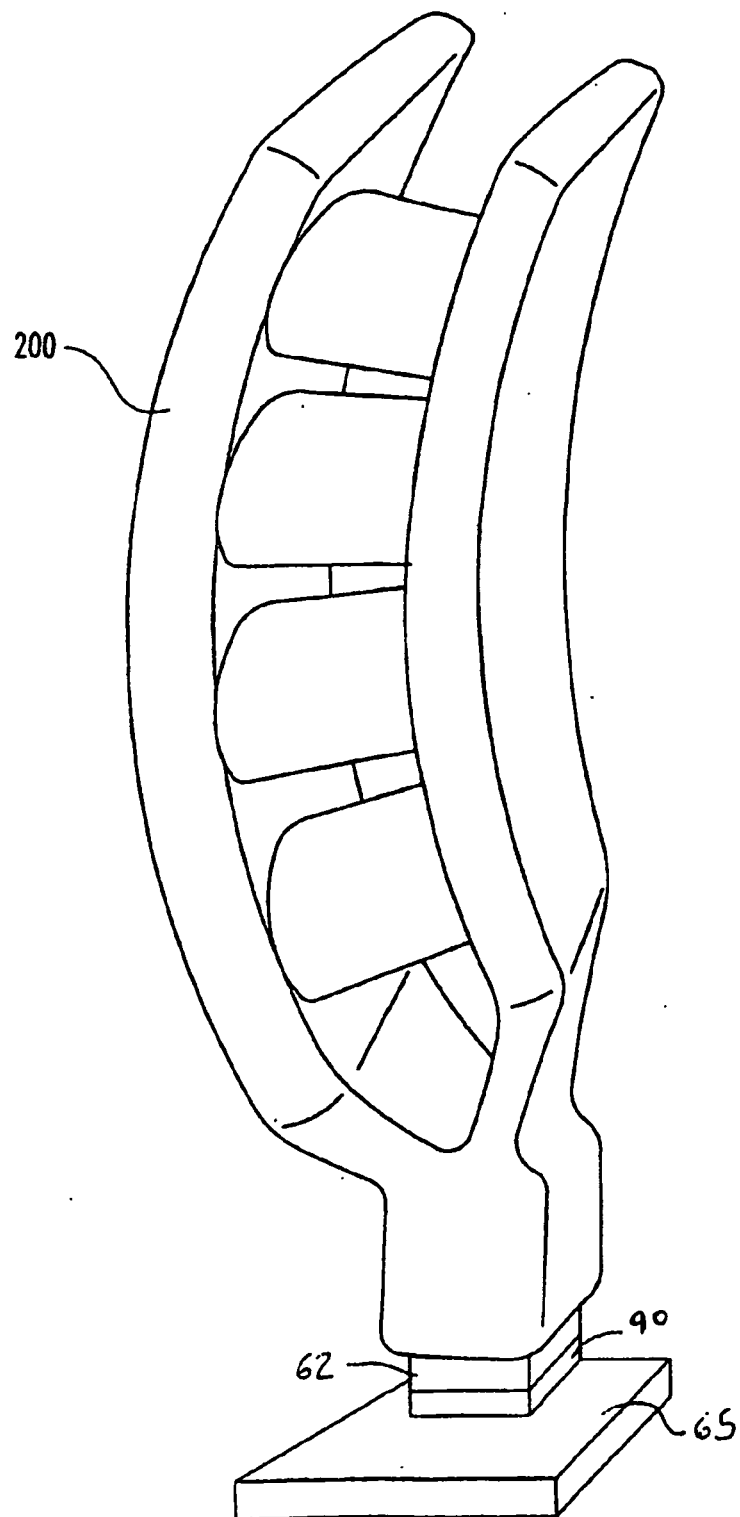


Fig. 4

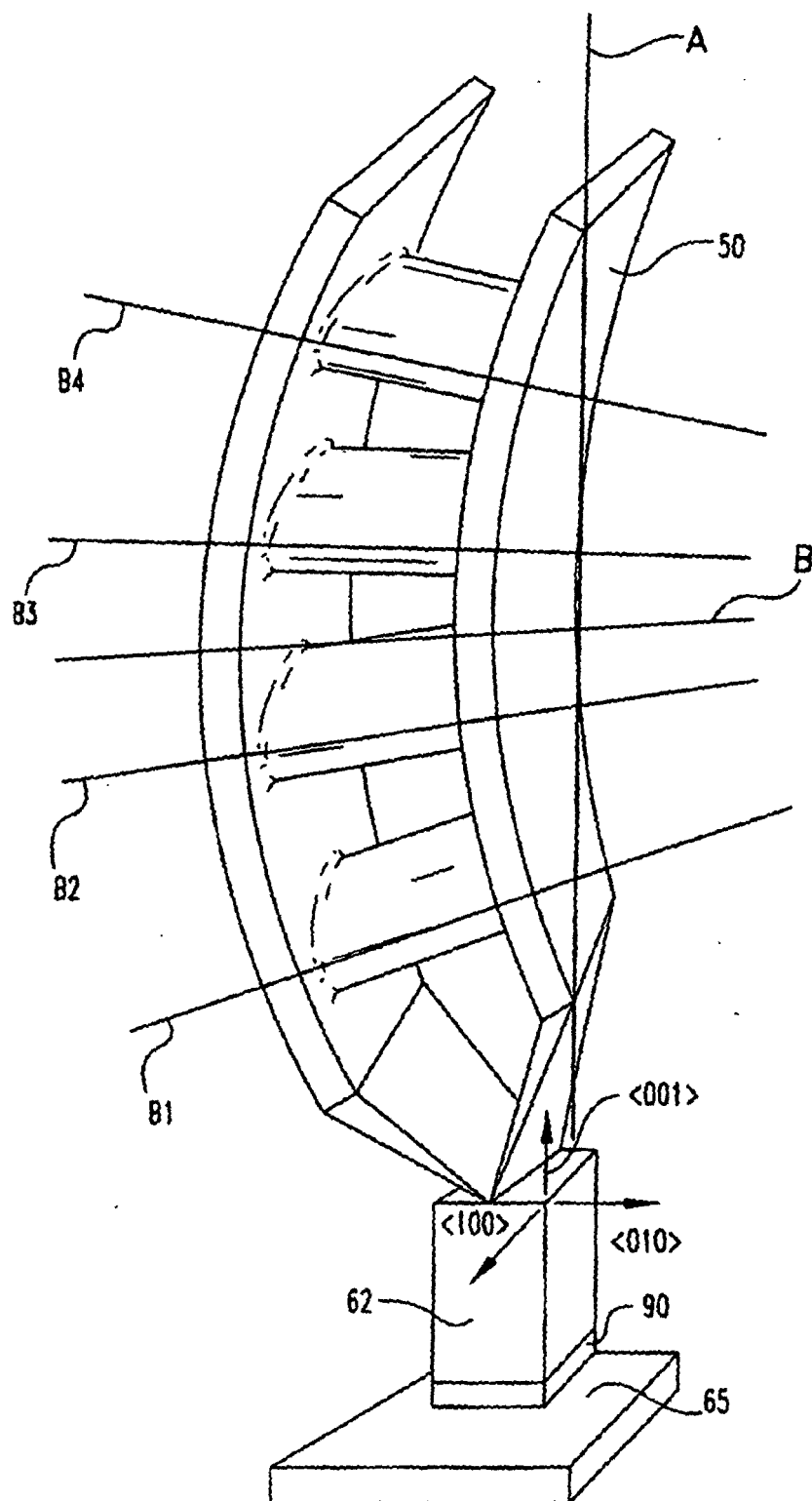


Fig. 5

REFERENCES CITED IN THE DESCRIPTION

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