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

(11) EP 2 105 616 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
30.09.2009 Bulletin 2009/40

(21) Application number: **07850962.7**

(22) Date of filing: **20.12.2007**

(51) Int Cl.:
F04D 29/30 *(2006.01)* ***C23C 4/10*** *(2006.01)*

(86) International application number:
PCT/JP2007/074527

(87) International publication number:
WO 2008/087830 (24.07.2008 Gazette 2008/30)

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR

(30) Priority: **15.01.2007 JP 2007005852**

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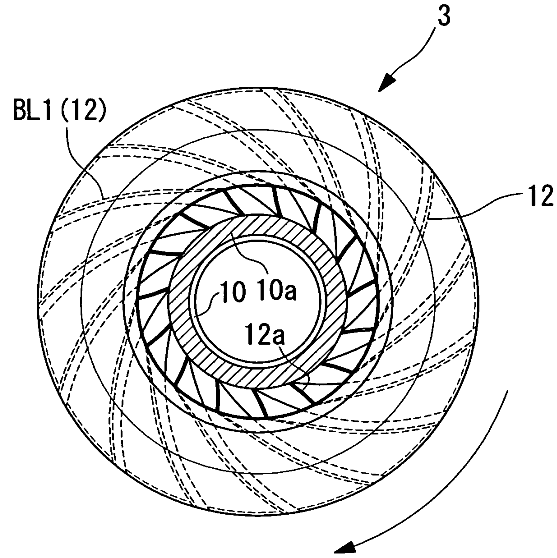
(54) IMPELLER FOR GAS COMPRESSOR AND GAS COMPRESSOR WITH THE SAME

(57) An object is to provide a gas-compressor impeller which has excellent durability even when gas containing solid particles is compressed and which does not increase the cost. A gas-compressor impeller (3) installed in a gas compressor that compresses gas containing solid particles has a hub portion (10) and a plurality of blades (12) extending substantially radially from the outer circumferential surface of the hub portion (10). The hub portion (10) and the blades (12) are rotated about the central axial line to compress gas. The blades (12) have abrasion-resistant films (20) only at gas inlet portions.

FIG. 2A



Printed by Jouve, 75001 PARIS (FR)

Description

Technical Field

[0001] The present invention relates to a gas-compressor impeller for compressing gas containing solid particles and to a gas compressor having the same.

Background Art

[0002] Gas compressors designed to mainly compress gas such as air sometimes need to compress gas contaminated with solid particles, depending on the use. For example, gas compressors for compressing air used in ironworks sometimes compress air contaminated with iron oxide.
Thus, if gas is contaminated with solid particles, damage to impellers due to solid particles cannot be ignored. To prevent damage from solid particles, Patent Document 1 discloses a technique in which a compressor member is plated with a nickel-phosphorus alloy.
[0003] On the other hand, though not directed to a gas compressor, Patent Document 2 discloses a technique in which cermet particles containing tungsten carbide are thermally sprayed on a water wheel or pump for pumping liquid to form an abrasion-resistant thermal-spray film to prevent abrasion by hard particles (slurry erosion).
[0004]

Patent Document 1: Japanese Unexamined Patent Application, Publication No. 2001-200390
Patent Document 2: Japanese Unexamined Patent Application, Publication No. 2005-187890 ([0002], [0003], [Table 1], etc.)

Disclosure of Invention

[0005] However, because the technique disclosed in Patent Document 1 forms an abrasion-resistant film by plating, the durability is not sufficient.
In addition, because the aforementioned document does not disclose the region where the abrasion-resistant film is formed, it is assumed that the entire compressor member is plated. However, because gas-compressor impellers, among others, have three-dimensional shapes, in the case of electrolytic plating, it is difficult to form a film whose thickness is adjusted to a desired value. Thus, sufficient durability may not be obtained.
[0006] Patent Document 2 discloses an abrasion-resistant thermal-spray film composed of a cermet material mainly containing tungsten carbide. However, Patent Document 2, in every respect, relates to a water wheel or pump intended for liquid or slurry, which does not compress gas. Therefore, as disclosed in Table 1 of Patent Document 2, although a slurry erosion evaluation is conducted, the adhesiveness of the abrasion-resistant film with respect to solid particles that collide at a higher speed than slurry (for example, solid particles floating in gas) is not taken into consideration at all.
When an abrasion-resistant film is used for a gas-compressor impeller, solid particles collide with the abrasion-resistant film at various angles. At this time, when the solid particles collide with the abrasion-resistant film at a substantially right angle (for example, a collision angle of 60° or greater), the impact force during the collision is great. When this impact force is great, the abrasion-resistant film may peel off. That is, no matter how high the abrasion resistance of the abrasion-resistant film, if the adhesiveness thereof is low, it cannot withstand the impact force during the collision of the solid particles and may peel off. Accordingly, abrasion-resistant films for gas-compressor impellers need to exhibit not only abrasion resistance but also adhesiveness.
In addition, similarly to Patent Document 1, Patent Document 2 does not disclose the region where the abrasion-resistant film is provided at all.
[0007] The present invention has been made in view of such circumstances, and the object thereof is to provide a gas-compressor impeller which has excellent durability even when gas containing solid particles is compressed and which does not increase the cost, and a gas compressor having the same.
Another object of the present invention is to provide a gas-compressor impeller provided with an abrasion-resistant film having not only abrasion resistance but also adhesiveness, and a gas compressor having the same.
[0008] To overcome the above-described problems, the present invention employs the following solutions.
A gas-compressor impeller according to a first aspect of the present invention is installed in a gas compressor that compresses gas containing solid particles. The impeller has a hub portion and a plurality of blades extending substantially radially from an outer circumferential surface of the hub portion. The hub portion and the blades are rotated about a central axial line to compress gas. The blades have abrasion-resistant films only at gas inlet portions.
[0009] As a result of intensive study, the present inventors have found that, in impellers used in gas compressors that compress gas containing solid particles, damage to the gas inlet portions of the blades is significant but there is com-

paratively no advancement of damage to the other portions. Thus, in the first aspect of the present invention, the abrasion-resistant films are provided only at the gas inlet portions of the blades. Accordingly, because the abrasion-resistant films need to be only locally provided, the durability of the impeller can be easily improved at low cost.

[0010] Furthermore, in the gas-compressor impeller according to the first aspect of the present invention, formation regions of the abrasion-resistant films provided only at the gas inlet portions may be provided from connecting positions of the blades to the hub portion in a height direction of the blades, and the size of the formation regions in the height direction of the blades may be gradually reduced from leading edges of the blades toward a downstream side.

[0011] The damage from the solid particles contained in the gas is significant on the hub portion side of the blades, i.e., the base side of the blades. Therefore, the formation regions of the abrasion-resistant films are provided from the connecting positions of the blades to the hub portion in the height direction of the blades.

The damage from the solid particles contained in the gas gradually decreases from the leading edges of the blades toward the downstream side. Thus, it is preferable that the size of the formation regions of the abrasion-resistant films in the height direction of the blades be gradually reduced from the leading edges of the blades toward the downstream side.

[0012] Furthermore, in the gas-compressor impeller according to the first aspect of the present invention, the formation regions of the abrasion-resistant films provided on ventral sides of the blades may be larger than the formation regions of the abrasion-resistant films provided on back sides of the blades.

[0013] Because the ventral sides of the blades are the pressure faces, they are more severely damaged than the back sides of the blades. Thus, it is preferable that the formation regions of the abrasion-resistant films on the ventral sides of the blades be larger than the formation regions of the abrasion-resistant films on the back sides of the blades.

[0014] Furthermore, in the gas-compressor impeller according to the first aspect of the present invention, the abrasion-resistant films may be composed of a cermet material formed by thermally spraying a composite mainly containing tungsten carbide.

[0015] In a gas compressor that compresses gas containing solid particles, collision energy is great because of the high-speed solid particles. Accordingly, the abrasion-resistant films need to have not only abrasion resistance but also adhesiveness so as not to be peeled off upon collision of the solid particles. In the first aspect of the present invention, by making the abrasion-resistant films from a cermet material formed by thermally spraying a composite mainly containing tungsten carbide, not only abrasion resistance but also adhesiveness can be ensured.

Examples of the composite mainly containing tungsten carbide (WC) include WC-NiCr, WC-Co, and WC-CoCr.

A preferable thermal spraying method is ultra high-speed flame thermal spraying because it provides a great particle-flying speed to improve adhesiveness.

[0016] A gas compressor according to a second aspect of the present invention includes any one of the above-described gas-compressor impellers.

[0017] Because the gas compressor according to the second aspect of the present invention includes any one of the above-described gas-compressor impellers, a gas compressor having excellent durability can be provided even when gas containing solid particles is compressed.

A centrifugal compressor is suitable as the gas compressor.

[0018] According to the present invention, because the abrasion-resistant films are provided only at the gas inlet portions of the blades, a gas-compressor impeller having excellent durability can be provided at low cost.

In addition, in the present invention, by using a cermet material formed by thermally spraying a composite mainly containing tungsten carbide as the abrasion-resistant films, not only abrasion resistance but also adhesiveness of the abrasion-resistant films can be improved.

Brief Description of Drawings

[0019]

[FIG. 1] FIG. 1 is a schematic vertical sectional view showing a gas compressor according to an embodiment of the present invention.

[FIG. 2A] FIG. 2A is a front view of an impeller according to an embodiment of the present invention.

[FIG. 2B] FIG. 2B is a perspective view of an impeller according to an embodiment of the present invention, showing the back side of a blade.

[FIG. 3A] FIG. 3A is a perspective view of the impeller of FIG. 2A.

[FIG. 3B] FIG. 3B is a perspective view of the impeller of FIG. 2A, showing the ventral side of a blade.

[FIG. 4A] FIG. 4A is a plan view showing a sample used in an abrasion resistance test.

[FIG. 4B] FIG. 4B is a side view showing the sample used in the abrasion resistance test.

[FIG. 5] FIG. 5 is a schematic view showing the configuration of an experimental device used in the abrasion resistance test.

[FIG. 6] FIG. 6 is a schematic perspective view showing an abraded portion formed in the sample.

[FIG. 7] FIG. 7 is a graph showing an example of measurement data of the abrasion depth.
[FIG. 8] FIG. 8 is a graph showing the abrasion resistances according to this embodiment and according to comparative examples.
[FIG. 9A] FIG. 9A is a plan view of a sample used in an adhesiveness test.
[FIG. 9B] FIG. 9B is a side view of the sample used in the adhesiveness test.
[FIG. 10] FIG. 10 is a schematic view showing the configuration of an experimental device used in the adhesiveness test.
[FIG. 11] FIG. 11 is a graph showing the adhesiveness according to this embodiment and according to the comparative examples.

Explanation of Reference Signs:

[0020]

1: gas compressor
3: impeller
10: hub portion
12: blade
14: shroud
20: abrasion-resistant film

Best Mode for Carrying Out the Invention

[0021] An embodiment of the present invention will be described below with reference to the drawings.
FIG. 1 shows a vertical cross-section of a relevant part of a centrifugal compressor (gas compressor) 1 according to this embodiment.
The centrifugal compressor 1 is used to compress air containing solid particles P such as, for example, iron oxide. The centrifugal compressor 1 has an impeller 3, an air-intake flow path 5 provided upstream of the impeller 3, and a discharge flow path 7 provided downstream of the impeller 3.
The impeller 3 is rotated about a central axial line L by a driving source (not shown). The impeller 3 has a hub portion 10, a plurality of blades 12 extending substantially radially from the outer circumferential surface of the hub portion 10, and a shroud 14 connected to the upper edges of the blades 12 and forming a flow path between the blades 12 and the hub portion 10.
The impeller 3 is made of low-alloy steel (for example, JIS SNCM431) or stainless steel (for example, SUS630).
In FIG. 1, reference numeral 12a denotes a leading edge of one of the blades 12, and arrows A denote flow lines of the compressed air.
[0022] As shown in FIG. 2A, in the front view of the impeller 3 viewed from the upstream side of gas flow, the leading edges 12a of the blades 12 are partially exposed. In FIG. 2A, the impeller 3 rotates clockwise.
FIG. 2B shows an enlarged perspective view of the leading edge side of the blade 12 denoted by reference numeral BL1 in FIG. 2A. The face of the blade shown in FIG. 2B is the back side face. As shown with hatching in FIG. 2B, an abrasion-resistant film 20 is formed at a gas inlet portion including the leading edge 12a of the blade 12. The abrasion-resistant film 20 is formed only at the gas inlet portion, not at the other portions.
A formation region of the abrasion-resistant film 20 is provided from a connecting position of the blade 12 to the hub portion (i.e., the base of the blade 12) in the height direction of the blade 12. The size of the formation region of the abrasion-resistant film 20 in the height direction of the blade 12 is gradually reduced from the leading edge 12a of the blade toward the downstream side of the gas flow. More specifically, it is preferable that the size, h, of the formation region of the abrasion-resistant film 20 in the blade's height direction at the leading edge 12a of the blade be set to about 3/4H, where H is the height of the leading edge 12a of the blade. It is also preferable that the formation region of the abrasion-resistant film 20 be formed such that the formation region is gradually reduced from the leading edge 12a of the blade to a position around L_L = h/2 on the downstream side.
As shown with hatching in FIG. 2A, the abrasion-resistant film is formed also at a central side 10a of the inlet portion of the hub 10.
[0023] FIG. 3A shows a perspective view of the impeller 3. As shown in FIG. 3A, openings 18 for discharging compressed gas are provided around the outer circumference of the impeller. As shown, the impeller 3 according to this embodiment is used in a centrifugal compressor that performs compression while radially deflecting gas flow flowing in the axial direction on the central axis side.
FIG. 3B shows an enlarged perspective view of the blade 12 denoted by reference numeral BL2 in FIG. 3A. The face of the blade shown in FIG. 3B is a ventral side face which receives the dynamic pressure of the gas taken in. As shown

with hatching in FIG. 3B, the abrasion-resistant film 20 is formed at the gas inlet portion including the leading edge 12a of the blade 12. The abrasion-resistant film 20 is formed only at the gas inlet portion, not at the other portions.
The formation region of the abrasion-resistant film 20 is provided from the connecting position of the blade 12 to the hub portion (i.e., the base of the blade 12) in the height direction of the blade 12. The size of the formation region of the abrasion-resistant film 20 in the height direction of the blade 12 is gradually reduced from the leading edge 12a of the blade toward the downstream side of the gas flow. More specifically, it is preferable that the size, h, of the formation region of the abrasion-resistant film 20 in the blade's height direction at the leading edge 12a of the blade be set to about 3/4H, where H is the height of the leading edge 12a of the blade. It is also preferable that the formation region of the abrasion-resistant film 20 be formed such that the formation region is gradually reduced from the leading edge 12a of the blade to a position around L_H = h on the downstream side.

[0024] As described above, the formation region of the abrasion-resistant film 20 provided on the ventral side of the blade 12 is larger than the formation region of the abrasion-resistant film (refer to FIG. 2B) provided on the back side of the blade 12.

[0025] The abrasion-resistant film 20 is a cermet material formed by thermally spraying a composite mainly containing tungsten carbide (WC). Examples of a suitable composite mainly containing tungsten carbide include WC-NiCr, WC-Co, and WC-CoCr. A preferable thermal spraying method is ultra high-speed flame thermal spraying.

[0026] As shown in FIG. 1, the centrifugal compressor 1 configured as described above takes in gas from the air-intake flow path 5, compresses the gas with the impeller 10, and then discharges the gas to the discharge flow path 7. The solid particles contained in the gas are subjected to centrifugal force when they pass through the impeller 10 and are concentrated on the hub portion 10 side. The abrasion-resistant films 20 are provided on the blades 12 so as to prevent damage from collision with these solid particles. Examples

[0027] The abrasion-resistant films 20 according to this embodiment have abrasion resistance and adhesiveness (peel resistance). Test results of the evaluation of their performances are shown below.

[Abrasion Resistance (Erosion-Resistance Property)]

(1) Samples

[0028] As shown in FIGS. 4A and 4B, for samples 21, SNCM431 having a size of 60 mm × 50 mm × 10 mm was used as a base material. Edges of the sample 21 were chamfered to C0.5. A wide surface 22 of the sample 21 was coated with an abrasion-resistant film and subjected to an experiment.

(2) Abrasion-resistant film

[0029] The abrasion-resistant film was formed by thermal spraying. As thermal spraying materials according to this embodiment, tungsten carbide (WC) cermet materials, namely, WC-27%NiCr, WC-10%Co-4%Cr, and WC-12%Co, were used. As comparative examples, Cr_3C_2-25%NiCr, Al_2O_3-3%TiO_2, and Cr_2O_3 were used. Their composition ratios are expressed in percentage by weight.

(3) Fabrication Process of Samples

[0030] First, each sample was degreased by trichloroethylene vapor degreasing. Then, using an alumina grid of #60, blasting was performed at a gas pressure of 4 kgf/cm^2. Then, thermal spraying was performed under the following conditions to form an abrasion-resistant film.

(i) The present invention: WC cermet materials (WC-27%NiCr, WC-10%Co-4%Cr, and WC-12%Co)

- Thermal spray gun : JP-5000 (Eutectic of Japan, Ltd.)
- Conditions : Standard conditions of JP-5000 (ultra high-speed flame thermal spraying)
- Thickness : 0.5 mm

(ii) Comparative Example: Cr_3C_2 cermet material (Cr_3C_2-25%NiCr)

- Thermal spray gun : JP-5000 (Eutectic of Japan, Ltd.)
- Conditions : Standard conditions of JP-5000 (ultra high-speed flame thermal spraying)
- Thickness : 0.5 mm

(iii) Comparative examples: alumina-titania (Al_2O_3-3%TiO_2) and chromium oxide ceramic (Cr_2O_3)

· Thermal spray gun : F4 (Sulzer Metco (Japan) Ltd.)
· Conditions : Standard conditions of F4 (plasma thermal spraying)
· Thickness : 0.5 mm

[0031] After the abrasion-resistant films were formed by thermal spraying under the above-described conditions, grinding was performed using a diamond wheel.

(4) Test method

[0032] As shown in FIG. 5, each samples 21 was blasted with a predetermined amount of conical silica sand, serving as hard particles, from a nozzle 24, and the amount of abrasion was measured. The angle formed between the sample 21 and the conical silica sand ejected from the nozzle 24 was set to 60°. The distance between the nozzle 24 and the sample 21 was set to 93 mm. The amount of shot was set to 350 g at 4.7 g/sec. The collision speed of the ejected conical silica sand was set to give substantially the same energy as that of an actual apparatus in which iron oxide (Fe_3O_4) having a particle diameter of 3 μm is blasted at 115 m/s; in this test, it was set to 52 m/s. The conditions of this test are shown in the following table.

[Table 1]

ITEM	SET VALUE FOR TEST	REMARKS
Average Particle Size of Sprayed Silica	6.3μm	Composition(SiO_2:99.74%, Al_2O_3: 0.05%, Fe_2O_3:0.005%)
Projection Angle	60°	
Projected Amount of Silica	350g (4.7g/sec)	
Projection Speed of Particles	52m/s (set to give the same particle collision energy as that given by particle projection in practice) The projection speed of particles is calculated using Hinze & Zijnen equation with the provision that it is the same as the speed of air flow.	The energy is intended to be the same as that in practice. Colliding Particles Causing Erosion in Practice : Fe_3O_4 Particle Diameter : 3μm Collision Speed : 115m/s

(5) Method of Measuring Amount of Abrasion

[0033] As shown in FIG. 6, the abrasion depth of an abraded portion 25 formed in each sample 21 was measured with a contact-type surface-roughness meter in triplicate and the average value was obtained. Arrows shown in FIG. 6 indicate the scanning direction of the contact-type surface-roughness meter.
FIG. 7 shows an example of data at the time of measuring the amount of abrasion. In FIG. 7, the abscissa represents the scanning distance of the contact-type surface-roughness meter and the ordinate represents the abrasion depth (amount of abrasion).

(6) Test Result

[0034] FIG. 8 shows the result of the above-described test. The abrasion resistance factor shown in the ordinate in FIG. 8 is the value obtained by dividing the amount of abrasion (abrasion depth) of the base material SNCM431 having no abrasion-resistant film by the amount of abrasion (abrasion depth) of each sample having the abrasion-resistant film. Accordingly, the smaller the amount of abrasion of the sample, the larger the abrasion resistance factor.
As is clear from FIG. 8, the abrasion-resistant films composed of the WC cermet materials according to this embodiment provide greater abrasion resistance factors compared to those according to the comparative examples.

[Adhesiveness (Peel Resistance)]

(1) Samples

[0035] As shown in FIGS. 9A and 9B, for samples 27, SNCM431 having a size of 100 mm × 30 mm × 5 mm was used as a base material. Edges of the sample 27 were slightly chamfered. A wide surface 28 of the sample 27 was coated with an abrasion-resistant film and subjected to an experiment.
The fabrication processes of the abrasion-resistant films and of the samples were the same as those of the above-described abrasion resistance test. However, in the adhesiveness test, the grinding step performed in the abrasion resistance test after formation of the abrasion-resistant film was not performed.

(2) Test Method

[0036] Using a bending test apparatus shown in FIG. 10, the bending limit radius of the abrasion-resistant films was measured.
The bending test apparatus had a bending jig base 30 for supporting each sample 27 from below at two points and a bending jig 32 for pressing the sample 27 downward at a single point. The sample 27 with a coating surface 29 having the abrasion-resistant film facing down was placed on the bending jig base 30, and a pressure was applied to the sample 27 from above with the bending jig 32. Thus, three-point bending was performed.
The tip portion, which served as the pressing portion of the bending jig 30, had three radii, namely, 5 mm, 10 mm, and 25 mm. The bending speed, i.e., descending speed, of the bending jig 30 was 1 mm/s or less. Regarding the number of samples, one sample was used under each condition, and a total 15 samples (three bend radii × five types of abrasion-resistant film) were used.
The presence or absence of peeling was determined by carrying out observation at 20 times magnification with a microscope.

(3) Test Result

[0037] FIG. 11 shows the test result of the adhesiveness test. The ordinate in FIG. 11 represents the peeling limit bend radius (mm). Because a smaller peeling bending limit radius indicates the ability to resist a larger curvature without peeling, it can be said that the adhesiveness is large.
As is clear from FIG. 11, the abrasion-resistant films composed of the WC cermet materials according to this embodiment all show a peeling limit bend radius of 5 mm. Accordingly, it can be said that the abrasion-resistant films according to this embodiment have greater adhesiveness than those according to the comparative examples, each having a peeling limit bend radius of 10 mm or 25 mm.
[0038] As has been described, the abrasion-resistant films composed of the WC cermet materials according to this embodiment have not only abrasion resistance but also adhesiveness. The reason for the improved adhesiveness may be as follows.
The abrasion-resistant films composed of the WC cermet materials according to this embodiment were formed by "ultra high-speed flame thermal spraying" using combustion gas flames as a heat source. On the other hand, the abrasion-resistant films composed of alumina-titania and chromium oxide ceramic according to the comparative examples were formed by "plasma thermal spraying" using plasma as a heat source. In the ultra high-speed flame thermal spraying, the particle-flying speed is 500 m/s or more, which is much faster than the particle-flying speed in the plasma thermal spraying (from 100 m/s to 200 m/s). Therefore, in the ultra high-speed flame thermal spraying, the collision energy of the thermal spraying particles with the base material is great, whereby the adhesiveness is greater compared to that obtained in the plasma thermal spraying.
In addition, the WC powders according to this embodiment have larger specific gravities than the Cr_3C_2 powder according to the comparative example that employs the ultra high-speed flame thermal spraying similarly to this embodiment. Therefore, with the WC powders according to this embodiment, the thermal spraying particles have greater collision energy with the base material than the Cr_3C_2 powder according to the comparative example, thus giving greater adhesiveness.
Accordingly, the abrasion-resistant films according to this embodiment, which are composed of the WC cermet materials and formed by the ultra high-speed flame thermal spraying, have the best adhesiveness.
[0039] As has been described, according to this embodiment, the following advantages are obtained.
Because the abrasion-resistant films 20 are provided only at the gas inlet portions of the blades 12, that is, the abrasion-resistant films 20 are provided locally, the durability of the impeller 3 can be easily improved at low cost.
[0040] Damage from the solid particles contained in gas is severer at portions of the blades 12 closer to the hub portion 10, i.e., the base side of the blades 12. Therefore, in this embodiment, the abrasion-resistant films 20 are provided from

the bases of the blades 12 in the height direction of the blades. Damage from the solid particles contained in gas is smaller at portions farther from the leading edges 12a of the blades 12 toward the downstream side. Therefore, in this embodiment, the size of the formation regions of the abrasion-resistant films 20 in the blade's height direction is gradually reduced from the leading edges 12a of the blades toward the downstream side. Furthermore, the ventral sides of the blades 12 are pressure faces, which are damaged more severely than the ventral sides of the blades. Therefore, in this embodiment, the formation regions of the abrasion-resistant films 20 on the ventral sides of the blades 12 are larger than the formation regions of the abrasion-resistant films on the back sides of the blades 12. Thus, according to this embodiment, because the abrasion-resistant films 20 are formed only at the necessary portions, the durability of the impeller 3 can be improved without increasing the cost.

[0041] Because the abrasion-resistant films 20 according to this embodiment are composed of a cermet material formed by performing ultra high-speed flame thermal spraying of a composite containing tungsten carbide, not only abrasion resistance but also adhesiveness can be ensured. In a gas compressor that compresses gas containing solid particles, because the collision energy is great due to the high-speed solid particles, the abrasion-resistant films need to have not only abrasion resistance but also adhesiveness. Accordingly, the abrasion-resistant films are particularly useful.

Claims

1. A gas-compressor impeller installed in a gas compressor that compresses gas containing solid particles, the impeller having a hub portion and a plurality of blades extending radially from an outer circumferential surface of the hub portion, the hub portion and the blades being rotated about a central axial line to compress gas,
wherein the blades have abrasion-resistant films only at gas inlet portions.

2. The gas-compressor impeller according to claim 1,
wherein formation regions of the abrasion-resistant films provided only at the gas inlet portions are provided from connecting positions of the blades to the hub portion in a height direction of the blades, and
the size of the formation regions in the height direction of the blades is gradually reduced from leading edges of the blades toward a downstream side.

3. The gas-compressor impeller according to claim 2,
wherein the formation regions of the abrasion-resistant films provided on ventral sides of the blades are larger than the formation regions of the abrasion-resistant films provided on back sides of the blades.

4. The gas-compressor impeller according to any one of claims 1 to 3,
wherein the abrasion-resistant films are composed of a cermet material formed by thermally spraying a composite mainly containing tungsten carbide.

5. A gas compressor having the gas-compressor impeller according to any one of claims 1 to 4.

FIG. 1

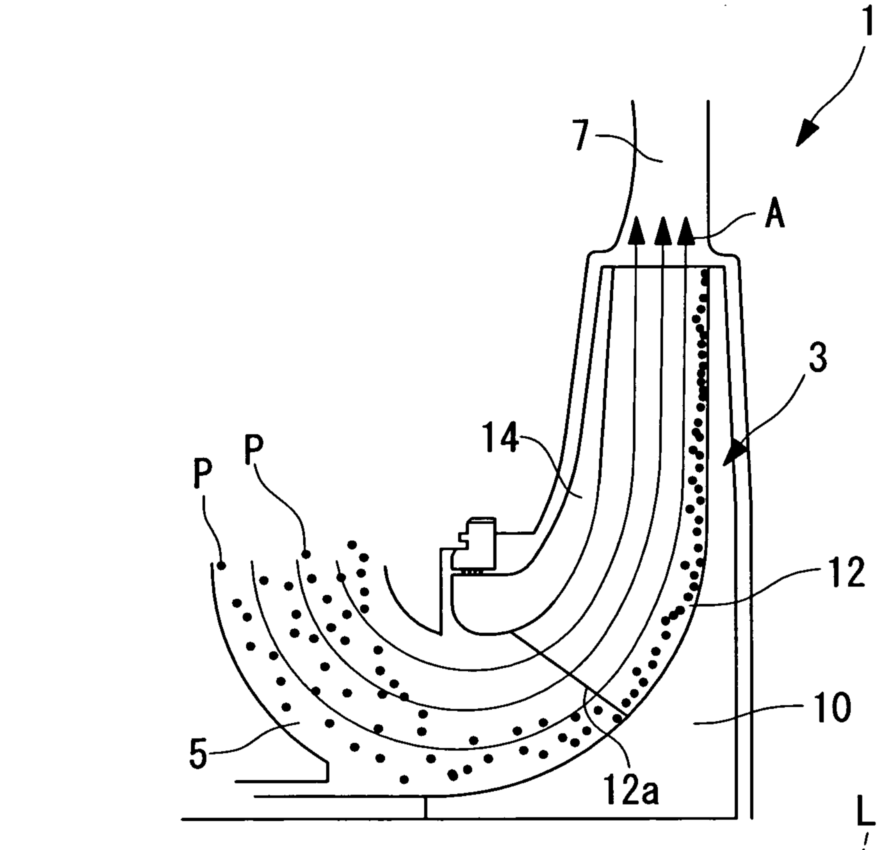


FIG. 2A

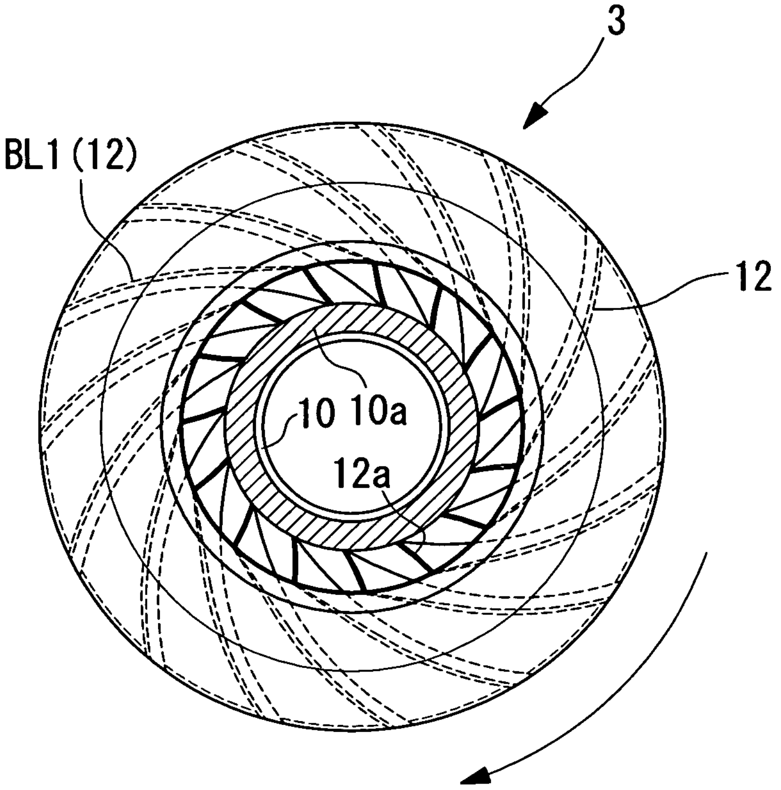


FIG. 2B

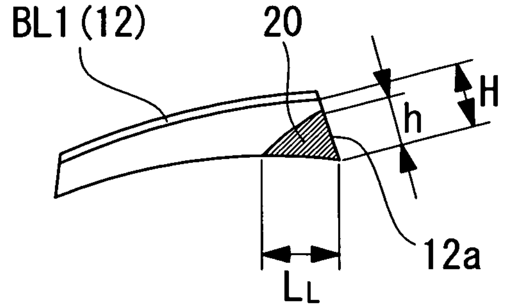


FIG. 3A

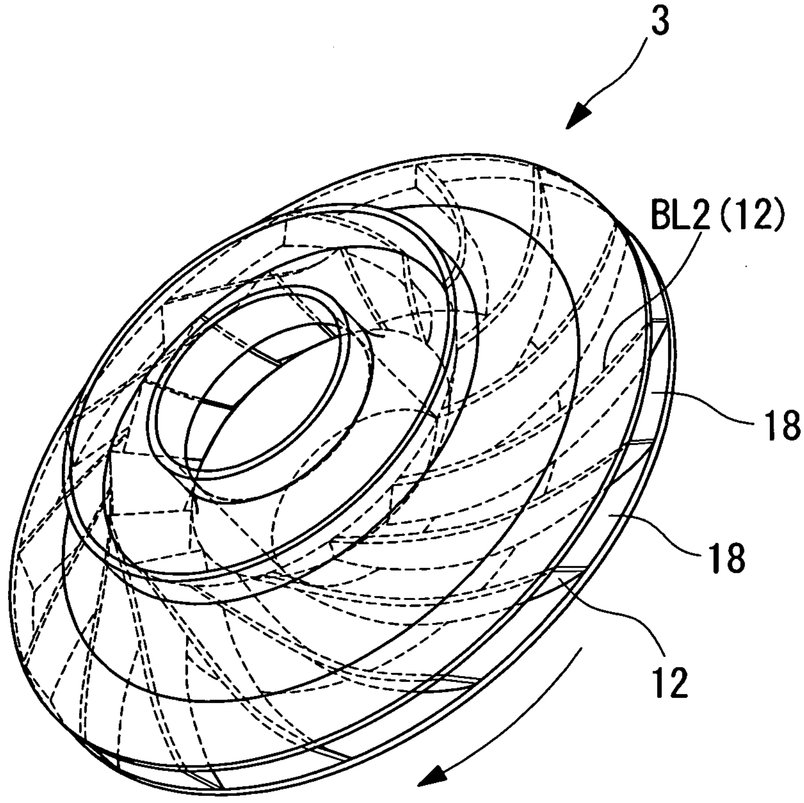


FIG. 3B

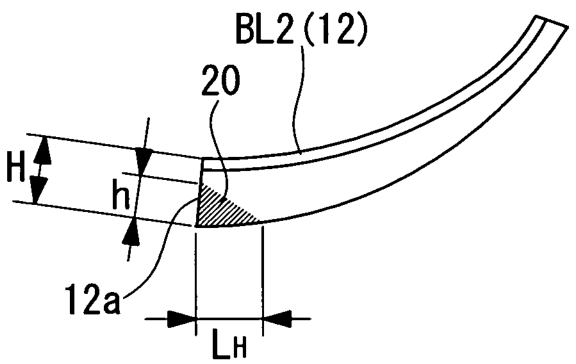


FIG. 4A

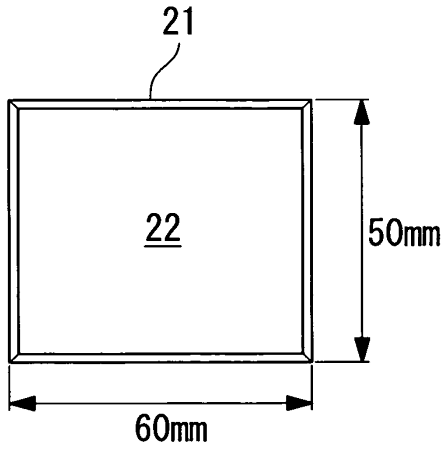


FIG. 4B

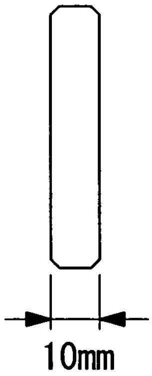


FIG. 5

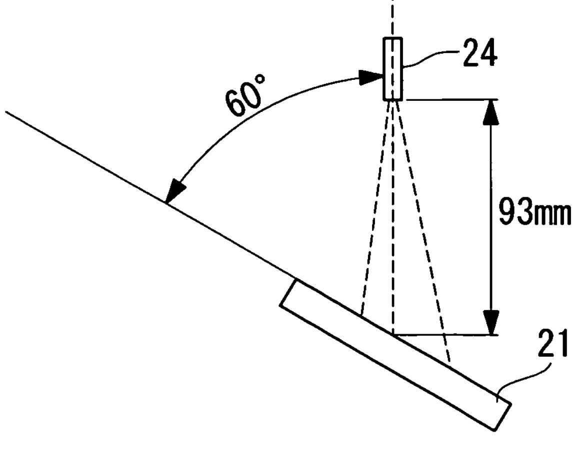


FIG. 6

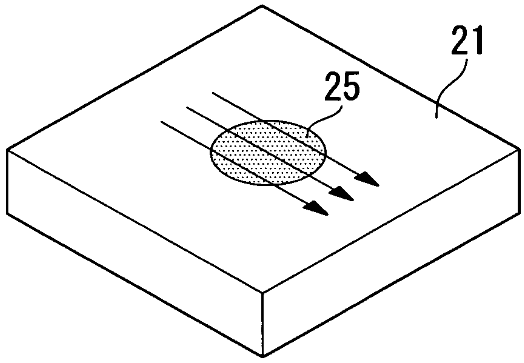


FIG. 7

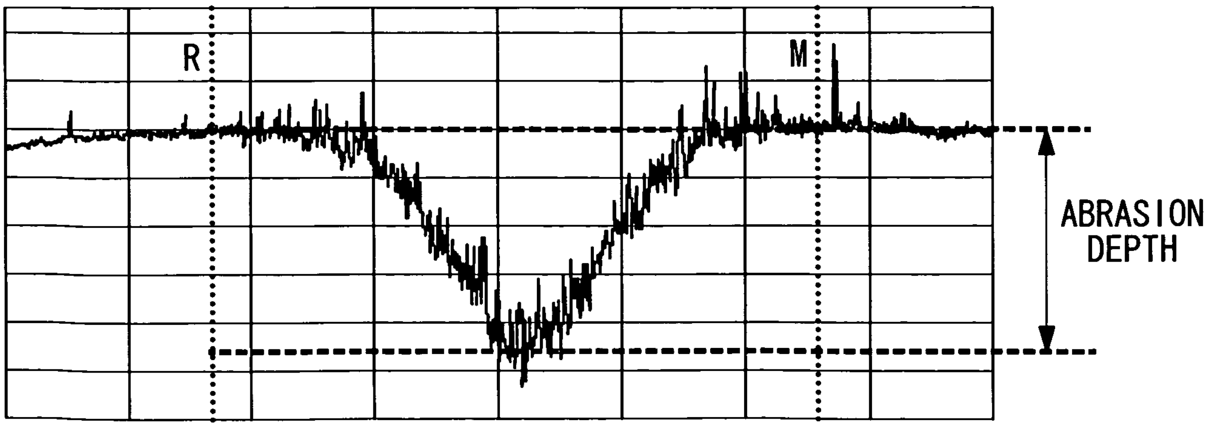


FIG. 8

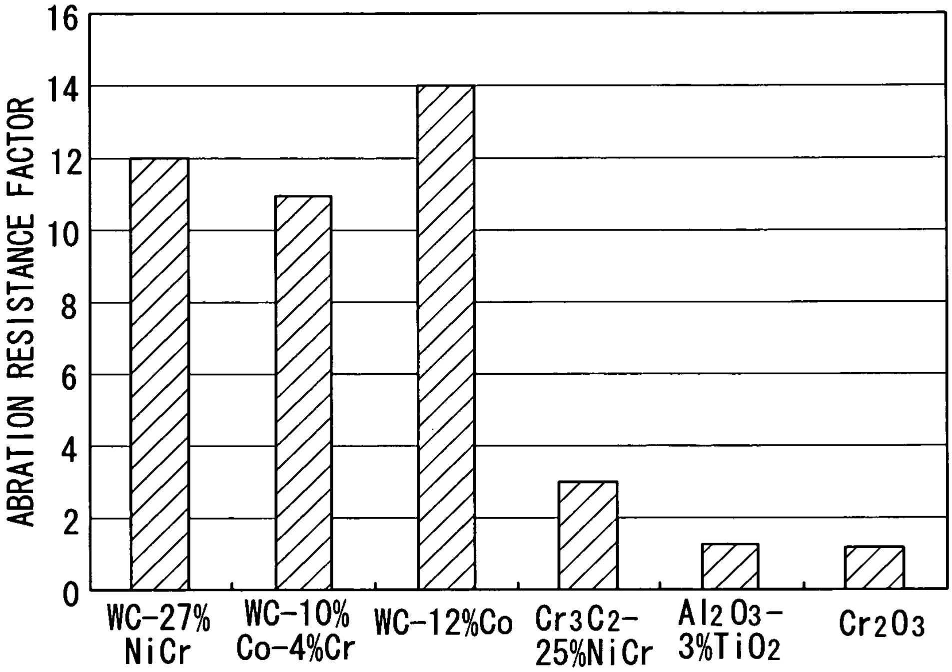


FIG. 9A

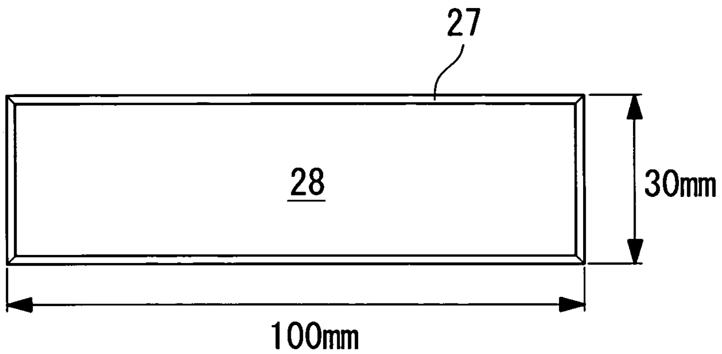


FIG. 9B

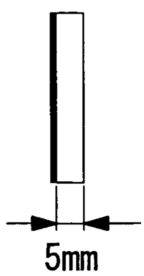


FIG. 10

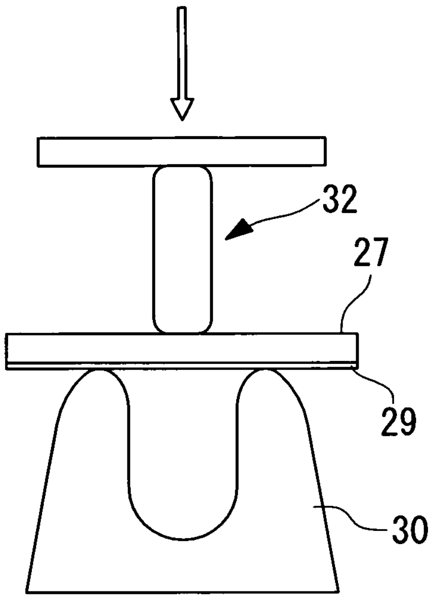
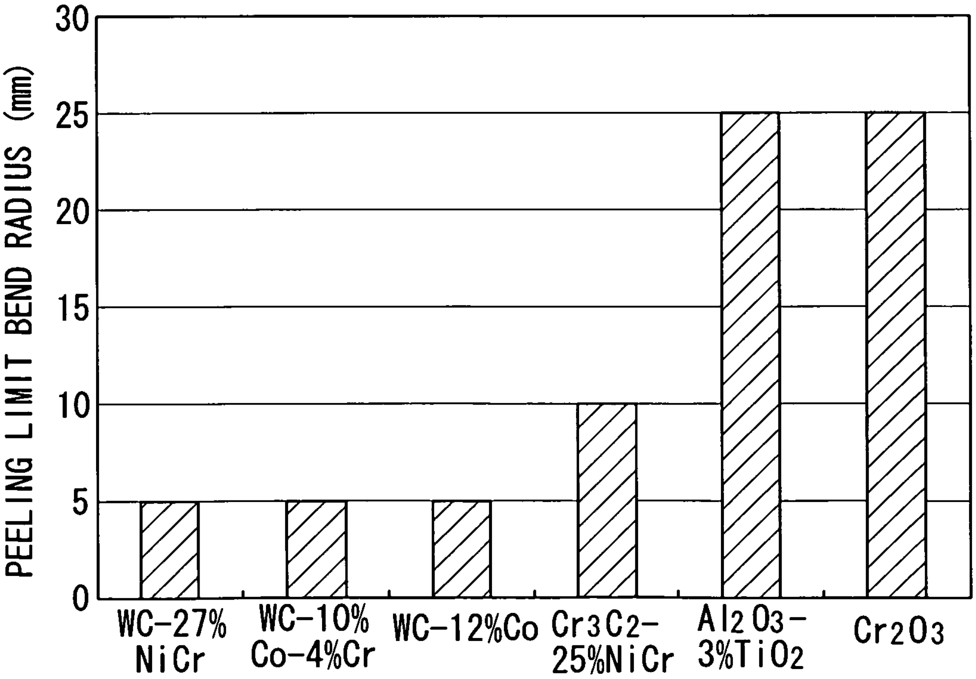

32
27
29
30

FIG. 11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0
5
10
15
20
25
30
WC-27% NiCr
WC-10% Co-4%Cr
WC-12%Co
Cr3C2-25%NiCr
Al2O3-3%TiO2
Cr2O3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2007/074527

A. CLASSIFICATION OF SUBJECT MATTER
F04D29/30(2006.01)i, *C23C4/10*(2006.01)i

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)
F04D29/30, C23C4/10

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2008
Kokai Jitsuyo Shinan Koho	1971-2008	Toroku Jitsuyo Shinan Koho	1994-2008

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 111176/1984(Laid-open No. 098791/1985) (Ebara Corp.), 05 July, 1985 (05.07.85), Page 1, line 17 to page 2, line 8; page 3, lines 13 to 20; page 5, lines 11 to 12; Figs. 1 to 2 (Family: none)	1,4-5
Y	JP 2003-268527 A (Nippon Steel Corp.), 25 September, 2003 (25.09.03), Par. Nos. [0011], [0017]; Fig. 7 (Family: none)	1,4-5

☒ Further documents are listed in the continuation of Box C.　　☐ See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 February, 2008 (21.02.08)	04 March, 2008 (04.03.08)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2007/074527

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 006561/1986(Laid-open No. 119499/1987) (Ishikawajima-Harima Heavy Industries Co., Ltd.), 29 July, 1987 (29.07.87), Page 2, lines 9 to 14; page 3, lines 1 to 4; Figs. 4, 6 (Family: none)	1-5
A	JP 2006-316793 A (Hitachi, Ltd.), 24 November, 2006 (24.11.06), Par. No. [0071]; Figs. 25 to 26 & JP 3911730 B2	1-5
A	JP 2001-107833 A (Toshiba Corp.), 17 April, 2001 (17.04.01), Par. Nos. [0049] to [0051]; Figs. 1, 3 (Family: none)	1-5

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REFERENCES CITED IN THE DESCRIPTION

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- JP 2001200390 A **[0004]**
- JP 2005187890 A **[0004]**