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(54) **PROCESS FOR THE SURFACE TREATMENT OF TITANIUM, ITEMS MADE OF OR COATED WITH TITANIUM AND TREATED ACCORDING TO SUCH PROCESS**

VERFAHREN ZUR OBERFLÄCHENBEHANDLUNG VON TITAN, AUS TITAN HERGESTELLTE ODER MIT TITAN BESCHICHTETE UND NACH EINEM DERARTIGEN VERFAHREN BEHANDELTE GEGENSTÄNDE

PROCEDE DE TRAITEMENT DE SURFACE DE TITANIUM, ARTICLES A BASE DE TITANIUM OU RECOUVERTS DE TITANIUM ET TRAITES SELON LEDIT PROCEDE

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- **PATENT ABSTRACTS OF JAPAN vol. 007, no. 281 (C-200), 15 December 1983 (1983-12-15) & JP 58 161771 A (ITSUO SHINTANI), 26 September 1983 (1983-09-26)**
- **PATENT ABSTRACTS OF JAPAN vol. 1995, no. 07, 31 August 1995 (1995-08-31) & JP 07 090541 A (DEMUTETSUKU KK), 4 April 1995 (1995-04-04)**

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EP 1 354 071 B1

Description

[0001] The present invention refers to a process for the surface treatment of an item made of or coated with Titanium, in order to provide improved mechanical properties thereto.

[0002] The present invention further refers to items made of and coated with Titanium and subsequently subjected to a treatment according to said process and therefore provided with improved surface mechanical properties.

[0003] US-A-2892743 discloses a method of surface hardening for articles made of titanium or titanium base alloy in an atmosphere comprising 0.5-1.0% of at least one hydrocarbon gas and the balance essentially argon at a temperature in excess of about 788°C. EP-A-0885980 discloses a similar process for titanium and zirconium alloys where the surface hardening is carried out in an atmosphere containing one hydrocarbon under temperatures and pressures in the range 500-900°C and 100-900 mbar, respectively.

[0004] Among the mechanical properties of Titanium surfaces the non-stickiness thereof stands out, making this material suitable for applications in which the items made of or coated with Titanium are immersed or anyhow put in contact with liquid or pasty fluids, in a condition wherein a minimum fluid-surface friction or foulability be required.

[0005] Hence, viable applications may be found in several industrial sectors, like the food, petroliferous, paper, glue and likewise pasty aggregates manufacturing, or for the making of vessels, stirrers, valves, conveyors, ducts and the like.

[0006] Moreover, let us consider household applications, like non-stick coated pans and all the applications providing the employ of plastics substances, like the PTFE, liable to wear and deterioration.

[0007] To date said optimal non-stick features have not been fully exploited, as the surfaces at issue, when subjected to continuous stresses over time, are subjected to wear and consumption, phenomena compelling costly component replacements and possibly entailing pollution.

[0008] Hence, there is a demand for a process for the surface treatment of such items, so as to reinforce surfaces without adversely affecting the desirable non-stickiness thereof.

[0009] The technical problem underlying the present invention lies in providing a process capable of meeting this demand.

[0010] This problem is solved by carburizing, in a controlled way, the Titanium surface. In fact, the process provided according to the present invention comprises a heating step for items made of or coated with Titanium in a controlled atmosphere containing carburizing agents, characterized in that the heating step is carried out at a temperature higher than the phase transition temperature of Titanium, i.e. higher than 882.5°C, and at a pressure lower than 0.5 mbar in an atmosphere comprising one or more inert gases and a Carbon gas, the percentage of Carbon gas being higher than 30%.

[0011] According to a preferred version of the process, this temperature advantageously ranges from 950 to 1050°C.

[0012] The pressure whereat this step is carried out is advantageously equal to about 0.2 mbar, i.e., under vacuum beyond the controlled process atmosphere.

[0013] The duration of the heating time essentially depends on the temperature and on the Carbon content of the atmosphere: for >25% percents of Carbon gas and ≥ 850°C temperatures the treatment times are of at least 1 hour and may extend to over 6 hours.

[0014] The preferred percent for the Carbon gas concentration is advantageously equal to about 40%.

[0015] Employable inert gases are Nitrogen and Argon, whereas among Carbon gases of course Carbon and Hydrogen compounds having a <60 mol molecular weight are preferable. Two particularly effective gases are methane (CH_4) and acetylene (C_2H_2).

[0016] The items made of or coated with Titanium exhibit Carbon enrichment in the surface layers, an increase leading to a marked improvement of the mechanical performances of the surface.

[0017] However, it is understood that this treatment does not entail an excessive embrittlement of the latter.

[0018] In the case of the abovedescribed process, the effective penetration of the Carbon atoms extends down to a depth of 120 μm below the surface, with a notable content of Carbon, oxides and Titanium nitrides.

[0019] It is understood that the invention refers to all those items comprising a Titanium-base non-stick surface, treated according to the abovedescribed process. Owing solely to the wide range of employs, a listing of the viable items will be omitted. A mere few examples will be mentioned, among which valve bodies and shutters, stirrers, mixers, vessel coatings, components of machines operating on liquid or pasty fluids, conveyors, ducts and coatings thereof, machine components apt to slide one in contact with the other, slides, guides, wheels, etc.

[0020] In the comparative examples which will be described hereinafter, Titanium samples will be subjected to a heating step as hereto defined and each test piece will be measured in order to assess the effects of the treatment on the mechanical-physical performances thereof.

[0021] Then, an applicative example of the process itself, related to a valve shutter, will be disclosed.

Comparative examples

[0022] Some carburizing treatments were carried out using a high-vacuum oven whose main features are reported hereinafter:

* Dimensions of inner cylindrical chamber: diameter Ø= 250 mm; height h = 400 mm.
* Maximum working temperature T = 2000 °C (Tungsten resistors)
* Inert gases: Nitrogen and Argon

[0023] Overall, about 25 treatments were carried out, the most significant ones being disclosed in Tables 1.1 and 1.2. 200 x 100 x 3 mm test pieces superficially precleaned with acetone were used. Ten treatments were carried out under a 40% Argon/Methane atmosphere, the working pressure equal to 0.2 mbar was held, varying the treatment temperature (from 800 to 1050°C), and the treatment duration (from 1 to 6 hours).

Tab. 1.1 -

Carburizing treatments carried out with methane.			
Treatment initials	**Temperatur e (°C)**	**Duration (h)**	**Atmosphere**
A	800	1	40% Ar + CH_4
B	800	6	40% Ar + CH_4
C	1050	1	40% Ar + CH_4
D	1050	6	40% Ar + CH_4
E	950	1	40% Ar + CH_4
F	850	2	40% Ar + CH_4
G	850	6	40% Ar + CH_4
H	800	2	40% Ar + CH_4
I	950	2	40% Ar + CH_4
L	950	6	40% Ar + CH_4

Tab. 1.2 -

Carburizing treatments carried out with acetylene			
Treatment initials	**Temperature (°C)**	**Duration (h)**	**Atmosphere**
M	800	1	40% Ar + CH_4
N	800	2	40% Ar + CH_4
O	850	2	40% Ar + CH_4
P	950	1	40% Ar + CH_4
Q	950	2	40% Ar + CH_4

[0024] In order to assess the effect of the carburizing treatment onto the Titanium foils, techniques such as optical microscopy, spectroscopic analysis, hardness measuring, surface erosion and spectroscopy processes, X-rays, XPS, Hydrogen content measuring, wettability and wear strength tests were adopted.

Optical microscope observation and spectroscopic analysis

[0025] Initially, surface carburization of the samples was assessed by spectroscopic analyses. These techniques do not enable a quantitative Carbon analysis, yet a qualitative assessment is viable. Fig. 1 reports the spectra of the Ti tel quel (a) and of the sample A (b) representative of all the carburized samples at issue.

[0026] Comparing the peak heights (see the first peak on the left of the spectrum, almost nil for the sample of Titanium tel quel and higher in the sample A), the Carbon is found to be present in an equivalent quantity onto the surfaces of

the carburized foils, and in a greater quantity than that present onto the surface of the Ti tel quel. Therefore, regardless of the time interval and of the temperature, the carburizing treatments carried out have increased the concentration of the surface Carbon.

[0027] Following a metallographic attack carried out with Kroll reactant ($HF+HNO_3$ + distilled water) which. highlighted the structure of the materials and the thickness of the carburized layer, the sections of these foils have been observed under an optical microscope.

[0028] Micrographies taken from the samples enabled the observation that all the samples treated at 800 and 850°C, hence below the phase transition temperature of Titanium, exhibit a polygonal structure of an equiaxial α-type, similar to those of the Ti CP; the samples treated at 950 and 1050°C exhibit a different structure, with more elongated grains, suggesting a partial transformation from the a-type to the P-type structure ($\alpha+\beta$ acicular structure).

[0029] In some micrographies the carburized layer was apparent, with a thickness varying as a function of the temperature and of the duration of the treatment. Sample D exhibits a layer with a thickness of about 120 μm. Actually, subsequent EDS analyses highlighted the presence of a carburized layer of about 15 μm, a nitride-containing phase of about 100 μm and subsequently, for additional 5 μm, down to 120 μm a further carburized belt.

[0030] All the samples treated at 950°C exhibit an apparent carburized layer having a thickness of about 2040 μm.

[0031] For the foils treated at temperatures of 800 and 850°C the presence of a possible surface carburization could not be highlighted from the micrographies.

Hardness measurings

[0032] The sectional measurings of the hardness enable to single out an edge-to-edge hardness profile in order to assess any carburization and the thickness thereof.

[0033] The first measuring was carried out at about 10 - 25 μm from the surface, the subsequent ones from 100 μm to 1 mm thickness, then at mid-thickness (1.5 mm) and likewise starting from the opposite surface. The most significant measurings are reported in Table 1.3.

[0034] In the case of samples wherein the thickness of the carburized layer is in the order of several μms, these measurings do not prove significant to the end of singling out the carburized belt, as they are carried out in the matrix and not in the carburized layer. E.g., the samples A, H, M and N, treated at 800°C for 1 or 2 hours, do not exhibit an increase in hardness with respect to the Titanium tel quel.

Tab. 1.3 -

Results of the sectional microhardness measurings			
Sample Initials	**Hardness HV_{200g}**		
	about. 10 - 25 μm below surface	1.5mm (mid-thickness)	about 10 25 μm from opposite surface
TQ	181	13	166
A	174	123	164
B	268	140	148
C	249	148	271
D	927	271	841
E	237	162	237
F	274	142	264
G	450	189	437
H	206	116	168
I	478	124	478
L	503	178	498
M	157	146	161
N	181	122	189
O	401	147	351

Tab. 1.3 - (continued)

Results of the sectional microhardness measurings			
Sample Initials	**Hardness HV_{200g}**		
	about. 10 - 25 μm below surface	1.5mm (mid-thickness)	about 10 25 μm from opposite surface
P	420	151	297
Q	514	145	464

[0035] These measurings demonstrate that the sample D, treated at 1050°C for 6 hours, has undergone an apparent hardening process, reaching a subskin hardness equal to about 900 HV, way greater than that of the Ti CP tel quel, which generally exhibits a hardness in the neighborhood of 150-200 HV. This sample, at 100 μm below surface, still exhibits an elevated hardness, equal to 593 HV.

[0036] Also the samples G, I, L, O, P and Q, carburized at 850 and 950°C, exhibit a surface hardening equal to 400-500 HV, anyhow quickly decreasing down to 200 HV at about 100 μm below surface.

[0037] Also other samples exhibit a slight hardening, markedly lower than that sustained by the sample D.

Surface analysis

[0038] An analysis of the type providing surface erosions and spectroscopic measurings was carried out on the carburized samples, in order to assess the thickness of the carburized layer and any presence of undesirable elements like O and N under the various thermal treatment conditions.

[0039] The analysis was also carried out on a sample of Titanium tel quel (TQ) adopted as reference.

[0040] The results highlighted the following:

* The TQ sample merely exhibits a slight surface contamination from Carbon and a passivation oxide film;
* The graphs show that all the samples exhibit a carburized layer;
* The thickness of the carburized layer for the various samples is reported in Table 1.4.

Tab. 1.4 -

Carburized layer thickness of Ti samples	
Sample	**Thickness (μm)**
A (800°C, 1h)	3
B (800°C, 6h)	5
C (1050°C, 1h)	5
D (1050°C, 6h)	20
E (950°C, 1h)	7
F (850°C, 2h)	14
G (850°C, 6h)	8
H (800°C; 2h)	4
I (950°C, 2h)	16
L (950°C, 6h)	23
M (800°C, 1 h)	1.5
N (800°C, 2h)	2.5
O (850°C, 2h)	3
P (950°C, 1h)	14

Tab. 1.4 - (continued)

Carburized layer thickness of Ti samples	
Sample	**Thickness (μm)**
Q (950°C, 2h)	18

[0041] A significant example is represented by sample E, wherein the presence of Carbon, Oxygen and Nitrogen is detected down to a depth of about 20 μm. The percent by weight of Oxygen in the carburized layer is of about the 3%, always lower than that of the Carbon. Moreover, about 1% Nitrogen is present.

[0042] The subsequent X-ray qualitative analysis of the samples confirms the presence of the abovementioned elements, in particular highlighting the presence of a nitride carbide Titanium wherein the C:N stoichiometric ratio is not lower than 0.7:0.3. The presence of TiO is also highlighted.

[0043] Moreover, on some samples the XPS analysis was carried out, thereby assessing the chemical composition of the outermost surface layers (Max. down to 60 nm), the various phases present therein and the change thereof as a function of depth. It was observed that the Titanium is present on the surface mainly as TiO_2, and to a lesser extent as TiC or TiN; depthwise, the quantity of TiO_2 decreases to the detriment of that related to the TiC and/or TiN. On the surface, the Carbon is mainly present as graphite or hydrocarbon; depthwise, the carbon-related component increases.

[0044] By way of example, in Table 1.5 the chemical composition of the outermost atomic layers of the sample D is reported.

Tab.1.5-

Chemical composition in atomic percent of the sample D, on-surface and at various depths										
Sample D										
Depth (nm)	Na	Fe	0	Ti	N	Ca	C	Cl	K	Zn
o	2.2	1.0	35.3	16.1	5.3	0.4	38.8	0.1	0.3	0.3
2	1.9	0.5	39.5	26.8	7.6	0.2	22.8	0.2	0.4	traces
5	1.7	0.7	40.5	28.1	7.8	0.1	20.5	0.4	traces	0
10	1.7	1.2	42.0	29.8	4.9	0.2	19.9	traces	0.2	0
20	1.1	0.3	43.5	32.7	2.7	0.1	18.5	0.7	0.1	0
30	0.7	0.4	45.3	32.6	3.2	0.2	17.4	traces	traces	0
40	1.0	0.7	44.9	33.9	2.5	0.2	16. 8	traces	traces	0
50	0.5	1.3	43.5	35,7	2.8	0.1	16. 1	traces	traces	0
60	0.4	2.1	43.5	34.9	3.3	0.1	15.7	traces	traces	0

Hydrogen content

[0045] Some carburized samples were measured for Hydrogen content. In Table 1.6 it can be seen that all the samples exhibit a hydrogen content lower than the maximum limit defined by the ASTM standards, set at 150 ppm. In particular, the samples M and N, treated at 800°C for 1h and 2h, respectively, exhibit the lowest Hydrogen content.

Tab. 1.6 -

Hydrogen content of carburized Ti samples	
Sample Initials	Hydrogen content (ppm)
C	60
D	49
I	92
M	30
N	33

Tab. 1.6 - (continued)

Hydrogen content of carburized Ti samples	
Sample Initials	Hydrogen content (ppm)
Q	66

Wettability measurings

[0046] On all the samples wettability measurings with deionized water were carried out, employing a cleaning procedure. For each foil 6 repetitions were carried out, except in the case of non-significant results; yielded values are reported in Table 1.7. In spite of a thorough cleaning of the samples, a high data scattering is observed; in some cases, a standard deviation of up to 27° was calculated. Observing the yielded measurings, it may however be remarked that for the samples carburized under acetylene atmosphere (M, N, O, P and Q) the standard deviation is generally lower.

Tab. 1.7 -

Wettability measurings on carburized Ti samples								
Initials	Contact angle						Average	Std. Dev. (°)
TQ	84	72	60	83	72	90	77	11
A	41	84	55	61	79	74	66	16
B	89	66	73	96	91	80	83	12
C	75	69	67	76	71	72	72	3
D	72	78	83	72	74	69	75	5
E	60	80	73	71	63	79	71	8
F	75	78	68	68	-	-	72	5
G	72	60	31	41	67	55	54	16
H	71	88	75	74	30	69	68	20
I	51	90	62	52	84	-	68	18
L	44	70	96	113	45	78	74	27
M	85	90	84	83	84	86	85	3
N	69	74	86	89	87	88	82	8
O	65	7 ì	71	60	74	-	69	6
P	68	70	72	79	78	-	73	5
Q	80	79	68	70	77	78	75	5

[0047] Adopting a method differing from the one hereto employed, which enabled a greater data reproducibility, several measurings of the contact angle were carried out. The method provides the measuring of the advancing and receding angles, which appeared more stable than the static angle measured with the sessile drop method. The results of the contact angle measurings carried out with water are reported in Table 1.8.

Tab. 1.8 -

Wettability measurings							
Sample initials	**Contact angle (°)**					**Average (°)**	**Std. Dev.** (°)
TQ	72	75	76	74	75	74	1.5
A	-	-	-	-	-	84	3.0
B	-	-	-	-	-	46	4.3

Tab. 1.8 - (continued)

Wettability measurings							
Sample initials	**Contact angle (°)**					**Average (°)**	**Std. Dev.** (°)
I	133	135	131	130	127	131	3.0
N	122	121	128	127	129	125	4.0
Q	129	124	131	126	122	126	4.0

[0048] For these samples only the average value was provided.

[0049] Apparently, for the samples A, I, N and Q the carburizing treatment has increased the contact angle with respect to the TQ, therefore improving the non-stick properties of the material.

Wear strength tests

[0050] Stick-wear tests were carried out in order to assess the effect of the various treatments carried out on the Titanium foils on the wear strength thereof.

[0051] To carry out this test, a SRV-Optimol (Fretting) tribotester having a ball-plane contact geometry was used. The foil employed is made of Titanium, whereas the ball is made of 100Cr6. The test consists in oscillating (10Hz) the ball onto the foil, with a 3 mm width and applying a 20N load. The duration of the test is equal to 15 min. The wear strength is assessed measuring the post-test weight loss (ΔP) of the materials. The testing conditions were selected so as to discriminate the effect of the various treatments carried out on Titanium. Table 1.9 reports the yielded results.

Tab. 1.9 -

Wear test results						
Foil initials	**Load (N)**	**run (mm)**	**Frequency (Hz)**	**T (°C)**	**C.A.**	**foil ΔP (g)**
T. Q.	20	3	10	room	> 0.5	0.0050
A	20	3	10	room	> 0.5	0.0024
B	20	3	10	room	> 0.5	0.0027
C	20	3	10	room	> 0.5	0.0028
D	20	3	10	room	> 0.5	0.0024
E	20	3	10	room	> 0.5	0.0003
F	20	3	10	room	> 0.5	0.0027
G	20	3	10	room	> 0.5	0.0012
H	20	3	10	room	> 0.5	0.0039
I	20	3	10	room	> 0.5	0.0013
L	20	3	10	room	> 0.5	0.0014
M	20	3	10	room	> 0.5	0.0037
N	20	3	10	room	> 0.5	0.0033
O	20	3	10	room	> 0,5	0.0030
P	20	3	10	room	> 0,5	0.0016
Q	20	3	10	room	> 0.5	0.0012

[0052] With respect to the Ti TQ, All the samples exhibit an improvement of the tribological properties, and a sensibly smaller weight loss.

[0053] The samples treated at 950°C, for time intervals ranging from 1 to 6 hours under methane as well as acetylene atmosphere, exhibit an elevated wear strength; in particular, the sample E, carburized under methane atmosphere at 950°C for 1 hour, exhibits a weight loss of a mere 0.0003 g, whereas the samples L, P and Q exhibit a weight loss ranging from 0.0012 to 0.0016 g.

[0054] Also the sample G, treated at 850°C for 6h, exhibits an improvement of its tribological properties, suffering a weight loss of a mere 0.0012 g.

[0055] With reference to Fig. 2, a valve 1 of a hand-operated type is shown. It is understood that the present applicative example is mentioned purely by way of example, and not for limitative purposes.

[0056] This valve comprises a valve body 2 inside which a duct is formed. Therein, the valve 1 comprises a shutter member, in particular a shutter capable of rotating of 90°, by virtue of a handle 4, between a closing or shutting position and an opening position.

[0057] The shutter member at issue is to be destined to a continuous use during which it should endure a certain pressure and be subjected to mechanical fatigue and to friction with the other surfaces of the valve body.

[0058] Moreover, the surface of the shutter should have the least possible wettability, so that the presence of the valve, at open conduit, does not entail excessive flow resistance.

[0059] The shutter is foil- or plate-shaped. Advantageously, this plate is made of Titanium and it is subsequently treated according to the abovedisclosed process, e.g., alike sample D of the comparative examples.

[0060] Thus, this member will have a prolonged strength, an enhanced reliability, and it will introduce a reduced flow resistance by virtue of the reduced friction between the surfaces thereof and the fluid engaging the valve.

[0061] To the abovedescribed process and to items treated therewith, a person skilled in the art, in order to satisfy further and contingent needs, may effect several further modifications and variants, all however comprised in the protective scope of the present invention, as defined in the appended claims.

Claims

1. A process for the surface treatment of Titanium comprising a heating step for items made of or coated with Titanium in a controlled atmosphere containing carburizing agents, **characterized in that** the heating step is carried out at a temperature higher than the phase transition temperature of the Titanium, i.e. at a temperature higher than 882.5°C, and at a pressure lower than 0.5 mbar in an atmosphere comprising one or more inert gases and Carbon gas, the percentage of Carbon gas being higher than 30%.

2. The process according to claim 2, wherein the heating temperature ranges from 950° to 1050°C.

3. The process according to claim 1, wherein the duration of the heating time is of at least 1 hour.

4. The process according to claim 1, wherein employable inert gases are Nitrogen and Argon.

5. The process according to claim 1, wherein said Carbon gas are Carbon and Hydrogen compounds.

6. The process according to claim 5, wherein said Carbon and Hydrogen compounds have a <60 molecular weight.

7. The process according to claim 6, wherein said employable Carbon gases are methane (CH_4) and acetylene (C_2H_2).

8. An item (3), made of Titanium or comprising at least one surface coated with Titanium, treated by a process according to any one of the preceding claims.

9. The item (3) according to the preceding claim, including valve bodies and shutters, stirrers, mixers, vessel coatings, components of machines operating on liquid or pasty fluids, conveyors, ducts and coatings thereof, machine components apt to slide one in contact with the other, slides, guides, wheels.

Patentansprüche

1. Verfahren zur Oberflächenbehandlung von Titan, beinhaltend einen Erhitzungsschritt für Gegenstände, die aus Titan bestehen oder mit Titan überzogen sind, in einer kontrollierten Atmosphäre, die Aufkohlungsmittel enthält, **dadurch gekennzeichnet, dass** der Erhitzungsschritt bei einer Temperatur ausgeführt wird, die höher ist als die Phasenübergangstemperatur des Titans, d.h. bei einer Temperatur, die höher ist als 882,5 °C, und bei einem Druck, der niedriger als 0,5 mBar ist, in einer Atmosphäre, die ein oder mehrere Inertgase und Kohlenstoffgas enthält, wobei der Prozentsatz an Kohlenstoffgas höher als 30% ist.

2. Verfahren nach Anspruch 1, wobei die Erhitzungstemperatur von 950° bis 1050°C reicht.

3. Verfahren nach Anspruch 1, wobei die Dauer der Erhitzungszeit weniger als 1 Stunde beträgt.

4. Verfahren nach Anspruch 1, wobei verwendbare Inertgase Stickstoff und Argon sind.

5. Verfahren nach Anspruch 1, wobei das Kohlenstoffgas Kohlenstoff- und Wasserstoffverbindungen sind.

6. Verfahren nach Anspruch 5, wobei die Kohlenstoff- und Wasserstoffverbindungen ein Molekulargewicht von < 60 haben.

7. Verfahren nach Anspruch 6, wobei die verwendbaren Kohlenstoffgase Methan (CH_4) und Acetylen (C_2H_2) sind.

8. Gegenstand (3), hergestellt aus Titan oder versehen mit wenigstens einer Oberfläche, die mit Titan überzogen ist, behandelt durch ein Verfahren nach einem der vorhergehenden Ansprüche.

9. Gegenstand (3) nach dem vorhergehenden Anspruch, beinhaltend Ventilgehäuse und Verschlussstücke, Rührer, Mischer, Behälterüberzüge, Maschinenteile, die in flüssigen oder pastenartigen Fluids arbeiten, Förderer, Kanäle und Überzüge derselben, Maschinenteile, die in der sing, eines in Kontakt mit dem anderen zu gleiten, Schieber, Führungen, Räder.

Revendications

1. Procédé pour le traitement de surface de Titane comportant une étape de chauffage d'articles constitués ou revêtus de Titane dans une atmosphère commandée contenant des agents de cémentation, **caractérisé en ce que** l'étape de chauffage est effectuée à une température supérieure à la température de transition de phase du Titane, c'est-à-dire à une température supérieure à 882,5°C, et à une pression inférieure à 0,5 mbar dans une atmosphère comportant un ou plusieurs gaz inertes et du gaz Carboné, le pourcentage de gaz Carboné étant supérieur à 30 %.

2. Procédé selon la revendication 1, dans lequel la température de chauffage est dans la plage allant de 950° à 1050°C.

3. Procédé selon la revendication 1, dans lequel la durée du chauffage est d'au moins 1 heure.

4. Procédé selon la revendication 1, dans lequel des gaz inertes pouvant être utilisés sont de l'Azote et de l'Argon.

5. Procédé selon la revendication 1, dans lequel ledit gaz Carboné est constitué de composés Carboné et Hydrogéné.

6. Procédé selon la revendication 5, dans lequel lesdits composés Carboné et Hydrogéné ont un poids moléculaire < 60.

7. Procédé selon la revendication 6, dans lequel lesdits gaz Carbonés pouvant être utilisés sont le méthane (CH_4) et l'acétylène (C_2H_2).

8. Article (3), constitué de Titane ou comportant au moins une surface revêtue de Titane, traité à l'aide d'un procédé selon l'une quelconque des revendications précédentes.

9. Article (3) selon la revendication précédente, incluant des corps de vanne et des obturateurs, des agitateurs, des mélangeurs, des revêtements de récipient, des composants de machines agissant sur un liquide ou des fluides pâteux, des transporteurs, des conduites et des revêtements de celles-ci, des composants de machines capables de coulisser en contact les uns avec les autres, des glissières, des guides, des roues.

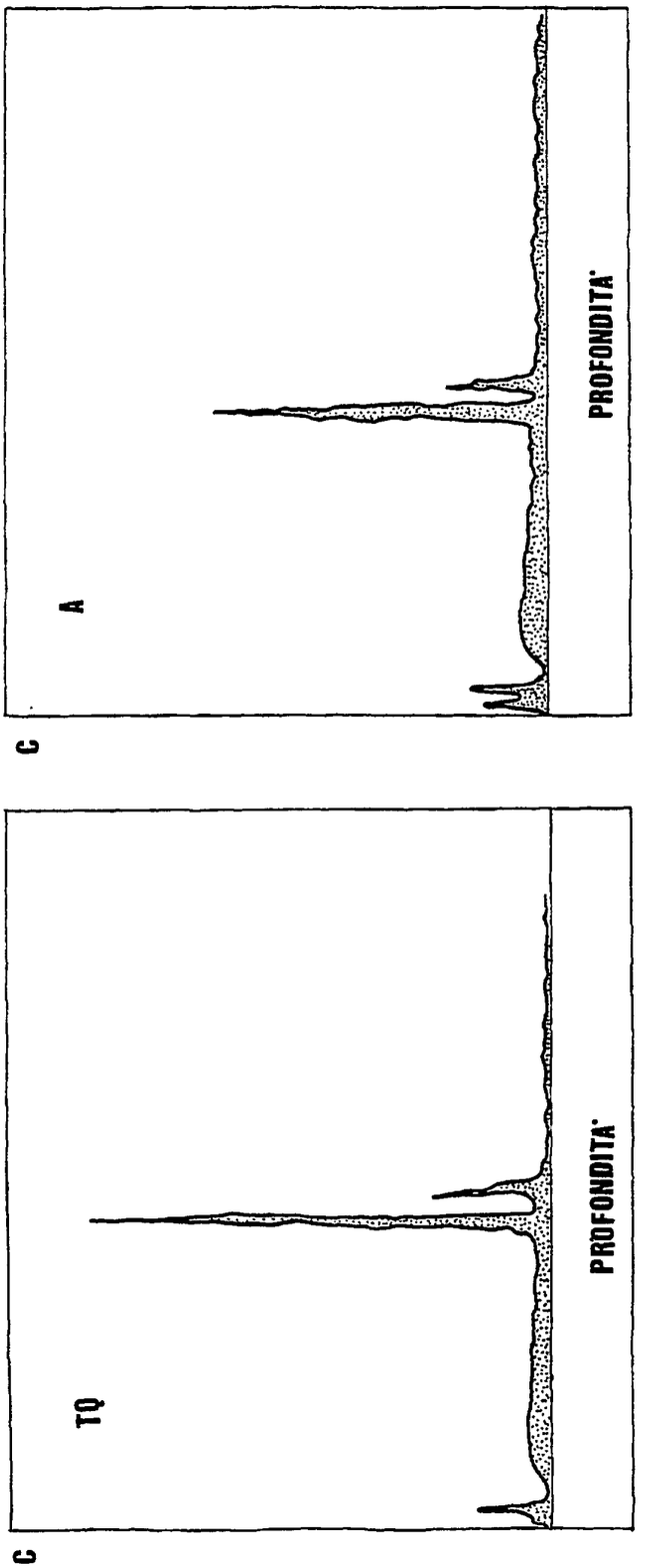


FIG.1

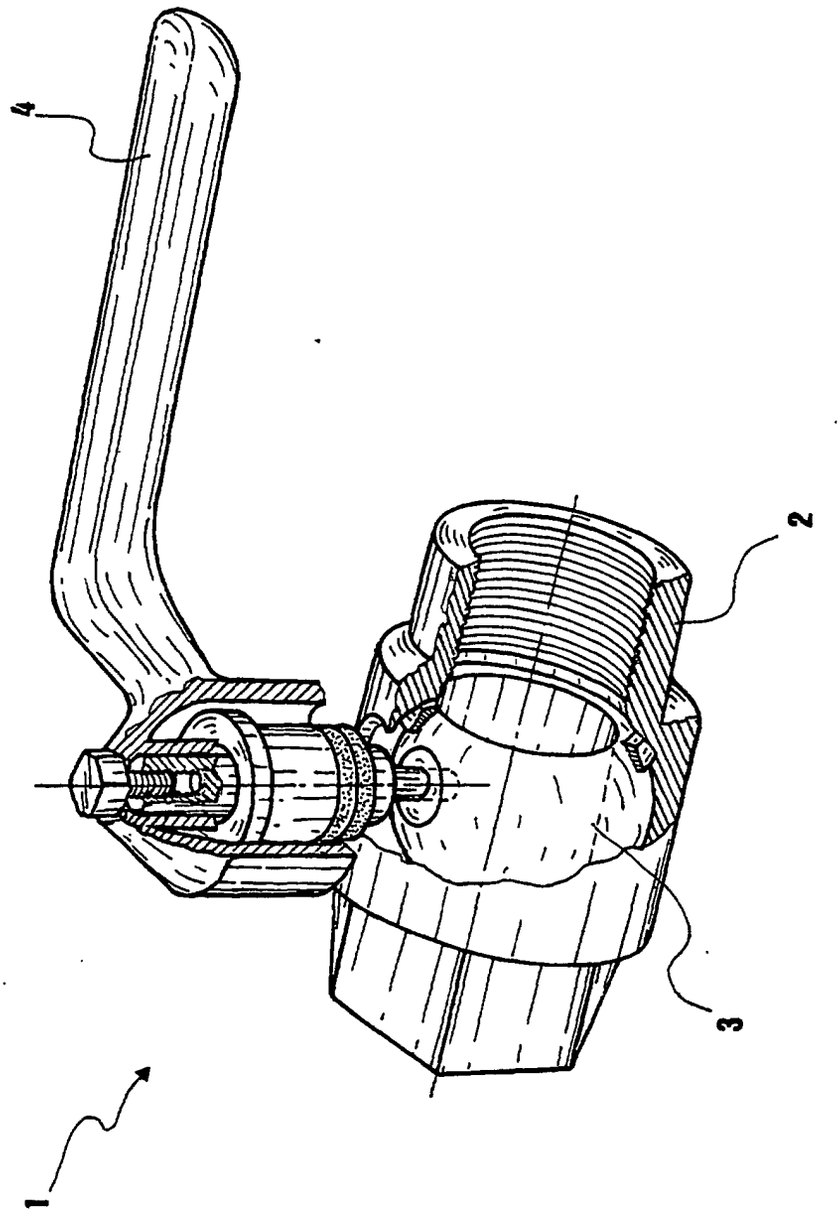


FIG.2