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(71) Applicants:
- **ANSALDO RICERCHE S.r.l. - Società per lo Sviluppo di Nuove Tecnologie**
  **16161 Genova (IT)**
- **John Crane Italia S.p.A.**
  **20053 Muggio (IT)**

(72) Inventors:
- **Casali, Donatella**
  **16161 Genova (IT)**
- **Guarnone, Paola**
  **16156 Genova (IT)**
- **Tiranti, Gianluca**
  **26900 Lodi (IT)**

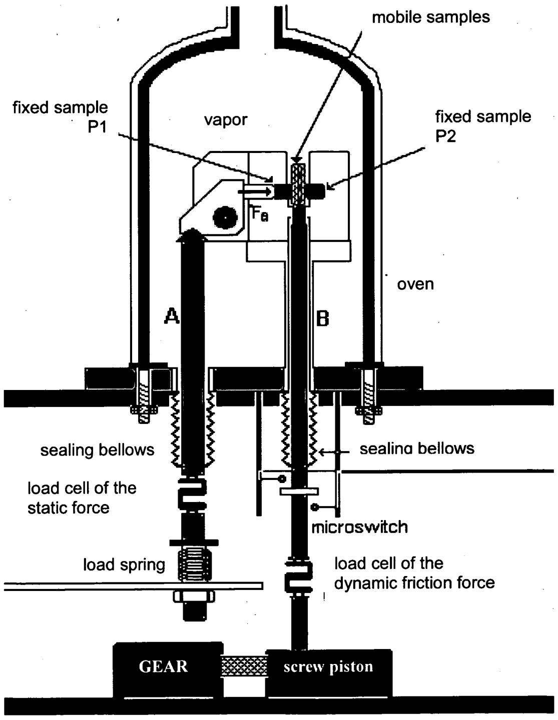
(74) Representative: **Gervasi, Gemma, Dr.**
**Notarbartolo & Gervasi S.p.A.,**
**Corso di Porta Vittoria, 9**
**20122 Milano (IT)**

# (54) CoCrC coating for surfaces liable to consumption

(57) Metallic product coated with a matrix of Co/Cr-alloy with a dispersed hard phase consisting of $Cr_3C_2$. Preferably the Co/Cr matrix comprises 60 to 96% of Co and 40 to 4% of Cr while the coating comprises $40\% \leq Co < 70\%$, $25\% \leq Cr < 50\%$. The $Cr_3C_2$ content is comprised between 30 and 60%.

According to a preferred embodiment of the invention, the Co/Cr matrix represents 45 to 70 wt% of the coating, preferably 55 to 70wt% and the $Cr_3C_2$ represents the 30-55wt%, preferably the 30-45wt%.

Fig. 1



EP 1 443 125 A1

## Description

### Field of the invention

**[0001]** The present invention refers to a coating of CoCrC for surfaces that undergo consumption, to their manufacturing process and to a mixture of powders of a Co/Cr-alloy with Cr carbides, e.g. $Cr_3C_2$ to obtain the coatings.

### Background art

**[0002]** In a European and worldwide context in which the nuclear energy is gradually abandoned and fuels like oil and natural gas are subjected to exhausting together with the fluctuation of their prices due to economical and practical reasons, coal becomes a valuable source for ensuring a reliable production of energy.

**[0003]** The users of coal plants for the production of energy require high yield and low $CO_2$ emissions, as recently pointed out by international agreements. To obtain. those goals, the attention is directed towards vapor plants having extremely critical parameters, like temperature and pressure. The technological limit for manufacturing components for heaters and turbines depends on the availability of materials capable of resisting to those working conditions.

**[0004]** From here derives the need to develop new materials having a performance at high temperatures that is similar to the one of known materials employed at lower temperatures.

**[0005]** The coatings based on Chromium carbides are already known for application with thermal spray technique. During this process the powders are heated and sprayed on the surface to be coated after partial or total fusion. The most commonly employed coating processes are:

- APS (Air Pressure Spray): an electric arc ionizes a gas mixture (usually $Ar/H_2$ or Ar He) generating a high temperature plasma (20000°C). The material to be deposited is injected in the form of powders directly in the plasma and here the exhausted gases accelerate at high speed the particles towards the surface to be treated. The particles are then mechanically bonded to the metallic substrate (which has been previously sanded) generating a coating with controlled porosity.
- S&F (Spray and Fuse): inside a gun producing an oxyacetylene flame the powders are injected and after being heated are projected at low speed towards the component to be coated, which has been previously sanded. They bind weakly with the metallic substrate and consequently an interdiffusion is made inside the base material through fusion with an oxyacetylenic tube or high-vacuum kiln. The adherence with the substrate is in this way enhanced by means of the chemical bonds between the two materials.
- HVOF (High Velocity Oxygen Fuel): a flame generated by a fuel in the gas form (Hydrogen Propane, Propylene, Kerosene ar others) and oxygen heats the injected powder, which is projected at high speed towards the element to be treated. The particles adhere mechanically on the metallic substrate (previously sanded) forming a coating with controlled porosity.
- Arc Spray: a wire containing the material to be applied or a wire made of the material itself is heated by means of an electric arc inserted in a gun and then sprayed on the surface to be coated. The adherence to the base material is weak and therefore depending on the specific use of the component after the spraying an optional fusion with oxyacetylenic tube or high-vacuum kiln can be performed.
- VPS or LPPS (Vacuum Plasma Spray or Low Pressure Plasma Spray): the process, which is very similar to the APS, is performed in a hypobaric chamber (under vacuum). The spraying apparatus results different relatively to the gun and the parameters involved, what leads to a better inhibition of the corrosion in the spraying phase, to a better mechanical anchorage to the substrate to be coated, as well as to an enhanced intrinsic porosity of the coating layer.

**[0006]** The powders employed in the various processes can be of various nature and chemical composition (ceramics, carbides, metal alloys and others). In the case of carbides, they are normally in the form of mixtures of one or more carbides with powders of metal alloys employed as binders. During the spraying process the carbides remain in the solid phase while the binding alloys melt and generate the coating layer in which the carbides particles are included.

**[0007]** EP-A-641 869 discloses an enhancement of the coatings with Chromium carbides and Ni80-Cr20 alloys. By using the HVOF technique weak coatings are formed with low resistance to erosion and insufficient smoothness, so that the powder components show the tendency to segregate. The document further teaches that the use of binders of Co alloys is unsuitable, because even if it could be used as an anti-consumption coating for relatively moving parts, this characteristic fails at high temperatures due to the insufficient heat resistance.

**[0008]** US-A-4 162 392 describes a method for hardening a metallic substrate by depositing by means of electric welding or with oxyacetylenic tube granules containing V, W and C from 5 to 40% in Wt of $Cr_3C_2$ and up to 15% in Wt of a mixture of Co, Fe, Mo and Ni.

**[0009]** Powders of Tungsten carbide and different other carbides, among which also $Cr_3C_2$, with a binder constituted of alloys of Ni and/or Co and Cr between 2 and 20Wt% are described in EP-A-214 679. Those mixtures are successively used for the production by synterisation of valve parts for internal combustion engines.

**[0010]** In US-A-3 993 446 the use of binders containing alloys CoCr is described, for mixtures of tungsten carbides and carbides of the transition metals.

**[0011]** In US-A-5 312 653 are described coatings intended for enhancing the consumption/erosion resistance of the pipe system of a Carbon combustion kiln with fluid bed for the production of vapor at working temperatures comprised between 300 and 450°C. The erosion is controlled by different factors: hardness of the eroding material and of the eroded surface; temperature, dimension, form, speed and impact angle of the eroding material; surface preparation, ductility and absence of porosity of the eroded surface.

**[0012]** In order to enhance the characteristics of mechanical resistance of the eroded surface the document suggests coatings containing Tungsten carbide or Niobium carbide in a ductile matrix made of an Co-Cr alloy deposited respectively with the S&F and with the HVOF techniques. The intrinsic characteristic of ductility of the matrix renders those coatings unsuitable for the protection of metallic parts, which has to resist to consumption and high temperature.

**[0013]** US-3 713 788 indicates as suitable for the resistance to consumption and to temperatures about 1100°C coatings of carbides/metallic matrix where the primary carbide is a carbide of a refractory metal chosen in the group consisting of TiC, CbC, VC and TaC and the metallic matrix is a Ni-Cr alloy with the presence of other metals like Ti, Fe, Al and Co, the latter in quantity up to the 25Wt%.

**[0014]** GB-A-933 406 teaches that powders made of alloys Co-Cr containing Si, C, 3-20% W and7or Mo, 15-35% Cr, 1-20% Ni and the remaining but not less than 25% of Co mixed with powders of WC with an average powder dimension not grater than 18 micron, deposited with the technique of the S&F on Fe-supports, enhance the resistance to consumption.

**[0015]** Composite coatings obtained by electrochemical deposition whereas a matrix with at least 50% of Co and particles included in the matrix of Chromium Carbide, where at least 50% of the particles have a diameter between 4 and 12 µm are described in US-A-5 558 758. Such coatings show an optimal resistance to consumption even after thermal treatment at 600°C. The electrochemical deposition does not ensure, for complex geometries, a uniform deposit of the particles in the Co-based matrix; furthermore, in order to minimize such disadvantages, it is necessary to position correctly the anodes relative to the element to be treated. In addition, the electrochemical deposition of heavy metals causes disposal problems of the process residues.

**[0016]** It is therefore an object of the present invention to find a new coating for steels which show a corrosion and consumption resistance equal or higher than the known ones, and in particular in oxidizing environments at high temperature, about 700-800°C.

**[0017]** Such coatings have to be compact and not porous, applicable to a vast range of base materials and easily restorable. Moreover, the process of manufacture must not be limited by the quantities and the dimensions of the components to be treated.

**[0018]** It has been now found that coatings obtained by means of thermal spray techniques, like for example by flame HVOF, by electric arc and by plasma PS, with the deposit of powders with a granulometry which is preferably greater than 0 and lower than 150 µm, preferably comprised between 11 and 150 µm, more preferably comprised between 11 and 53 µm, containing 55 to 70% of a Co-Cr alloy and 30-45% of $Cr_3C_2$, show a lower friction coefficient than the one obtained by using traditional welding coatings like stellite or by means of electrochemical deposition like the Tribomet®.

## Summary of the invention

**[0019]** The present invention refers to a metallic product coated with a Co/Cr-alloy matrix containing a dispersed hard phase preferably consisting of $Cr_3C_2$. Preferably, the matrix contains from 60 to 96% of Co and from 40 to 4% of Cr and the coating contains $40\% \leq Co < 70\%$, $25\% \leq Cr < 50\%$ and the chromium carbides are from 30 to 60%. In accordance to a preferred embodiment of the invention, in the metallic product the Co/Cr matrix represents the 45-70 wt% of the coating, preferably the 55-70 wt% and the $Cr_3C_2$ represents the 30-55 wt%, preferably 30-45 wt%. The coating of the metallic product contains in the Co/Cr matrix preferably from 70 to 95 wt% cobalt and from 5 to 30 wt% chromium and represents 55-65 wt% of the coating and the $Cr_3C_2$ is the 35-45 wt%, has a thickness between 20 and 1000 µm and a hardness between 30 and 40 HRC in the Rockwell-scale.

**[0020]** Furthermore, the present invention refers to a coating method for a metallic product wherein a metallic product is coated with thermal spray using a powder consisting of a Co-Cr-alloy based matrix with a dispersed hard phase made of chromium carbides $Cr_3C_2$ and a powder for metallic coatings by means of thermal spray technique according to claim 15, wherein the powder composition is $40\% \leq Co < 70\%$, $25\% \leq Cr < 50\%$ and the chromium carbides in the powder are 30-60 %.

## Brief description of the drawings

**[0021]** Further advantages of the invention will arise more clearly from the following description of a particular embodiment, which has no limiting character. The figures show:

Fig.1 - apparatus for consumption tests in vapor at high temperatures
Fig.2 - friction coefficient versus consumption path: comparison between the tests at 600°C and 720°C on the coating according to the present invention and the results of the tests at 550°C on commercial coating using the apparatus of Fig. 1.
Fig. 3 - friction coefficient versus consumption path: comparison between the tests at 600°C on the coating according to the present invention and the results of the tests on commercial coating
Fig.4 - friction coefficient versus consumption path: comparison between the tests at 720°C on the coating according to the present invention and the results of the tests on commercial coating
Fig.5 - section of the coating LC1C after the consumption tests at 720°C with in evidence of the formed cracks
Fig.6 - section of a stellite sample after the consumption tests at 720°C; in evidence a debris of stellite which is detached and deposited on the surface
Fig.7 - section of a sample of the coating according to the present invention after the consumption tests at 720°C
Fig.7.1 - detail of Fig.7 showing a section of the coating and of the oxide layer (dark-gray part at the top); the coating is homogenous and free from cracks

## Detailed description of the invention

**[0022]** The process according to the present invention comprises the steps of selecting a metallic substrate, like special alloys or stainless, austenitic or ferritic steel, providing a powdery alloy comprising a metallic matrix with a hard carbide included therein and coating the substrate with the powder at high temperature, generated by the combustion of a fuel mixture with oxygen. The coating is an alloy which comprises chromium carbide in a metallic matrix containing cobalt and chromium. The coating is preferably applied by means of an electric arc spray device with an oxyacetylene flame or plasma. According to a preferred embodiment of the invention, the alloy powder is a matrix based on chromium and cobalt and consists essentially of 60-96% cobalt and 4-40% chromium, preferably 90-95% cobalt and 5-10% chromium. From 45 to 70% of the metallic matrix is combined with 30-55% of $Cr_3C_2$, preferably 55-65% of the matrix with 35-45% of $Cr_3C_2$. The powders can be prepared by mechanical mixing or with other methods which allow the formation of aggregate forms like coated powders, block fused and milled powders or mechanically bonded powders. The powders are injected in the spray device in the form of fine powders having a granulometry comprised between 11 and 150 µm, preferably 11 and 53 µm.

**[0023]** The powder is injected by means of a carrier gas, preferably nitrogen or argon, wherein the fuel is preferably hydrogen. The substrate can be constituted by any kind of material, in particular steel and stainless-steel. In the process of supersonic flame spray the powders are injected directly in the flame, wherein the fuel stream is accelerated at 300 m/s. The powders are injected in the middle of the combustion flow. The sprayed deposit shows a lower porosity and a higher adhesion than the coating applied with spray techniques wherein the powders are accelerated at lower speed, like the plasma spray and the conventional flame spray. This is a key factor for the present invention, since the formation of fine and compact structure is an important criterion for a good consumption resistance. The thickness of the coating layer varies between 0,01 and 1 mm and the obtainable hardnesses are comprised between 30 and 40 HRC (300-400 HV).

**[0024]** The powders according to the present invention and used in the following examples have the following composition: 60% (94Co6Cr) + 40% $Cr_3C_2$.

**[0025]** In particular the powder composition is the following:

Sample A 56,4% Co, 38,3% Cr, 4,8% C
Sample B 56,4% Co, 36,1% Cr, 7,5%C

**[0026]** In order to test the behavior of the novel coating and to compare it with the commercial products, some consumption tests have been performed in vapor at 550°C, 600°C and 720°C.

**[0027]** Before the tests, the samples are heated in air at the test temperature with subsequent formation of an oxide layer on the surface, in order to simulate the working conditions in a plant. The consumption tests are performed on planar samples coated with the novel coating in vapor environment, which is heated at the test pressure at ca. 1,5 bar.

**[0028]** Prior to the vaporization, the water is purified by means of a resin and conditioned with ammonia for the purpose of maintaining the pH>9 during the tests.

**[0029]** The oxygen dissolved in the water is maintained below 10 ppb by employing a special resin or by insufflating argon or nitrogen in the water. The water is pumped in the test zone and a flow control device measures the water flow maintaining it at 0,2 Nl/h.

**[0030]** During the test the water vaporizes before arriving in the samples zone.

**[0031]** The test chamber comprises a vertical cylinder placed inside an oven.

**[0032]** Two couples of identical samples are tested together for providing double controlling.

**[0033]** Two mobile samples having a diameter of 35 mm and a thickness of 6 mm are mounted on a sample holder, which can move vertically (Fig.1) and are positioned between two fixed samples (diameter 25 mm, thickness 33mm).

**[0034]** The support structure of the mobile samples is connected to the shaft B of Fig.1. Said shaft B can move vertically with a speed of 1 mm/s. Two micro-switches regulate the inversion of the movement. The movement path of the samples during a cycle is 10 mm. The mechanical system that moves the shaft B is outside the oven containing the samples. A reduction gear drags a screw piston, which moves the shaft B. A load cell acquires the dynamic friction energy necessary to move the samples. Two microswitches control the direction changes. On the fixed sample P1 a static force is applied by a compression spring connected to the shaft A. A load cell acquiring the applied static force is positioned between the spring and the shaft. The fixed sample P2 is positioned so that it impacts against the fixed structure. Two sealing bellows are welded between the shaft A and the shaft B. The temperatures are measured by thermojunctions positioned inside the test chamber and located on the fixed samples. The tribometer is connected to a water line and to a control panel for the survey of temperature, friction forces, number of cycles and so on. The temperatures and the friction forces are acquired by means of a PC. The friction coefficient as a function of the consumption path is derived from the acquisition of the friction forces during the consumption test and from the number of cycles.

**[0035]** The friction coefficient $\mu$ is combined with the friction forces by the formula:

$$\mu = \text{dynamic friction force} / 2 \text{ static force}$$

**[0036]** In the figures 2, 3 and 4 is shown the friction coefficient as a function of the path covered during consumption tests in vapor at different temperatures on planar samples with the novel coating applied thereon, in comparison with the tests performed on commercial coatings. All tests have been conducted using the apparatus described in fig. 1.

**[0037]** The coating according to the present invention has been tested by depositing it as well with HVOF technique (JC HVOF) as with plasma spray in air technique (JC Plasma Spray).

**[0038]** The commercial coatings tested for comparison are the following:

**[0039]** LC1C, matrix Ni (75%) and Cr (25%) with dispersion of Chromium carbides, deposited with Detonation Gun or High Velocity Oxy Fuel process.

**[0040]** Stellite grade 6 (weld overlay), deposited with traditional welding techniques Plasma Transfer Arc (PTA) or Gas Tungsten Arc (TIG).

**[0041]** Tribomet ® T104CS $Cr_3C_2$ co-deposited with Co by electrodeposition.

**[0042]** Some tests have been performed with a smaller number of cycles but, in any case, the profile of the friction coefficient is well defined. The results refer to tests conducted

**[0043]** at different pressures, measured in MPa (i.e. different static forces applied to the fixed samples) and at different temperatures. The following table shows the meaning of the different symbols used in the graphs.

| | |
|---|---|
| LC1C 50 | homologous coupling, pressure 50MPa, 600°C |
| LC1C 25 | homologous coupling, pressure 25MPa, 600°C |
| LC1C10 | homologous coupling, pressure 10MPa, 600°C |
| LC1C 4 | homologous coupling, pressure 4MPa, 600°C |
| Trib 50 | homologous coupling, pressure 50MPa, 600°C |
| Trib 10 | homologous coupling, pressure 10MPa, 600°C |
| Trib/LC1 10 | coupling Tribomet and LC1C, pressure 10MPa, 600°C |
| 12TIG/LC1C 10 | coupling stellite TIG and LC1C, pressure 10MPa, 600°C |
| 12TIG/LC1C 50 | coupling stellite TIG and LC1C, pressure 50MPa, 600°C |
| JC Plasma Spray (sample B) 50 | homologous coupling, pressure 50MPa, 600°C |
| JC Plasma Spray (sample A) 50 | homologous coupling, pressure 50MPa, 600°C |
| JC HVOF 50 | homologous coupling, pressure 50MPa, 600°C |
| JC HVOF/LC1C 50 Stellite 10MPa 720°C | homologous coupling, pressure 50MPa, 600°C homologous coupling stellite PTA, pressure 10MPa, 720°C |
| LC1C 10MPa 720°C | homologous coupling , pressure 100MPa, 720°C |

(continued)

| | |
|---|---|
| JC Plasma Spray (B) 10MPa 720°C | homologous coupling, pressure 10MPa, 720°C |
| JC Plasma Spray(B) /Stellite 10 MPa 720C | homologous coupling JC Plasma Spay/Stellite PTA, pressure 10MPa, 720°C |
| LC1 C/Stellite 10MPa 720°C | coupling LC1C/Stellite PTA, pressure 10MPa, 720°C |
| Stellite 10MPa 550°C | homologous coupling Stellite PTA, pressure 10MPa, 550°C |
| LC1C 10MPa 550°C | homologous coupling LC1C, pressure 10MPa, 550°C |
| LC1C/Stellite 10MPa 550°C | coupling LC1C/Stellite PTA, pressure 10MPa, 550°C |

**[0044]** From the figures 2, 3 and 4 it can be noticed how the friction coefficient of the coating according to the present invention is lower than or equal to (i.e. a resistance to consumption which is greater or equal to) the one of the commercial coatings LC1C, Stellite grade 6 and Tribomet.

**[0045]** In particular, from Fig. 2 it can be noted how the coating according to the invention at 600°C shows a coefficient, which is clearly lower than the one of the commercial coatings at 550°C. At 720°C the novel coating shows a coefficient lower or equal to the one of the commercial coatings at 550°C.

**[0046]** Fig. 4 shows that the novel coating at 720°C has a coefficient lower or equal to the one of the commercial coatings. Between the homologous couplings only the curve of the LC1C coating shows lower coefficient values. It must be noticed in any case that the analysis conducted on the coatings after the tests at 720°C reveal that the coating LC1C has cracks of remarkable gravity which prejudice the behavior on consumption: if the tests would have been performed after a run of 5000 mm the coating would be detached and broken.

**[0047]** Further, Figure 4 indicates that between the non-homologous couplings, the coating according to the invention coupled to Stellite grade 6 has a behavior much better than that of the coating LC1C coupled to the satellite grade 6: the hardness of the LC1C coating is too high compare to that of the satellite which has a hardness similar to that of the new coating.

**[0048]** The metallographic characterization performed after the consumption tests has evidenced the superiority of the novel coating.

**[0049]** In particular, it arose that:

after consumption the stellite coating grade 6 shows adherence phenomena between the surfaces (Fig.6);
after consumption the LC1C coating shows cracks along its thickness (Fig.5);
after consumption the novel coating remains unchanged as well on the surface as along its thickness (Fig.7 and 7.1).

**[0050]** The cobalt/chromium matrix in the coating has the ability of forming a compact oxide on its surface, which is adherent and very resistant to consumption. This oxide reduces the friction coefficient and enhances the consumption resistance of the coating. Moreover, the oxide is incline to rebuild itself rapidly in oxidant environment.

**[0051]** The carbides containing component of the coating reduces the deformations and the risk of cracks.

**[0052]** Additional tests have been conducted with the purpose to study the stability of the new coating in oxiding environment:

- the coating has been aged 1000 hours in air to 720°C before the homologous and the friction coefficient resulted exactly similar to that reported in Fig.4, therefore it was not influenced by the treatment of pre-oxidation.
- The coating has been submitted to oxidation in vapor at 720°C up to 3000 hours. The results of the destructive analysis on the oxidized coating have shown a good resistance to the oxidation, best in vapor in comparison to the air, and effects of worsening have not been showed on the adhesion of the coating to the metal base.

## Claims

**1.** Metallic product coated with a Co/Cr alloy-based matrix having a hard phase dispersed in it, wherein said hard phase consists of $Cr_3C_2$.

**2.** Metallic product according to claim 1,
wherein the Co/Cr matrix contains from 60 to 96% of Co and from 40 to 4% of Cr.

**3.** Metallic product according to the claims 1 and 2, wherein the coating contains 40% ≤ Co < 70%, 25% ≤ Cr < 50% and the chromium carbides are 30-60%.

**4.** Metallic product according to the claims 1 to 3,
wherein the matrix is the 45-70 wt% of the coating, preferably 55-70 wt%, and the $Cr_3C_2$ represents 30-55 wt%, preferably 30-45 wt%.

**5.** Metallic product according to the claims 1 to 4,
wherein the Co/Cr matrix contains 70 to 95% of Co and 30 to 5% of Cr, preferably 90 to 95% of Co and 10 to 5% of Cr and represents the 55-65 wt% of the coating and the $Cr_3C_2$ represents the 35-45 wt%.

**6.** Metallic product according to the claims 1 to 5,
wherein the coating constituted by the Co/Cr matrix and the $Cr_3C_2$ hard phase has a thickness of 20 to 1000 µm and the hardness in Rockwell scale is comprised between 30 and 40 HRC.

**7.** Process for the deposition of a coating on a metallic product by means of thermal spray using a powder constituted by a Co/Cr-alloy matrix having a dispersed hard phase constituted by $Cr_3C_2$ with a granulometry grater than 0 and lower than 150 µm.

**8.** Process according to claim 7,
wherein the product undergoes subsequently a thermal treatment in vapor or in air at a temperature comprised between 600 and 800 °C.

**9.** Process according to claim 7 and 8,
wherein the thermal spray process is a HVOF flame, an electric arc or a Plasma Spray PS process.

**10.** Process according to the claims 7 to 9,
wherein the Co/Cr matrix contains 60 to 96% of Co and 40 to 4% of Cr and has a granulometry comprised between 11 and 150 µm.

**11.** Process according to the claims 7 to 10,
wherein the Co/Cr matrix represents 45-70 wt% of the coating and the $Cr_3C_2$ represents the 30-55 wt%.

**12.** Process according to the claims 7 to 11,
wherein the Co/Cr matrix represents 55-70 wt% of the coating and the $Cr_3C_2$ represents the 30-45 wt%.

**13.** Process according to the claims 7 to 12,
wherein the Co/Cr matrix contains 70 to 95% of Co and 30 to 5% of Cr, preferably 90 to 95% of Co and 10 to 5% of Cr and represents the 55-65 wt% of the coating and the $Cr_3C_2$ represents the 35-45 wt%.

**14.** Process according to the claims 7 to 13,
wherein the coating constituted by the Co/Cr matrix and the $Cr_3C_2$ hard phase has a thickness of 20 to 1000 µm.

**15.** Powder for metallic coatings by means of thermal spray wherein a hard phase constituted by chromium carbide $Cr_3C_2$ is dispersed in a Co/Cr-alloy matrix and the granulometry is grater than 0 and lower than 150 µm.

**16.** Powder according to claim 15,
wherein the composition of the metallic component in the powder is 40% ≤ Co < 70%, 25% ≤ Cr < 50% and the chromium carbides in the powder are 30-60% and the granulometry is comprised between 11 and 150 µm.

**17.** Powder according to the claims 15 and 16,
wherein the Co/Cr matrix contains 60 to 96% of Co and 40 to 4% of Cr.

**18.** Powder according to the claims 15 to 17,
wherein the Co/Cr matrix represents 45-70 wt% of the coating and the $Cr_3C_2$ represents the 30-55 wt%.

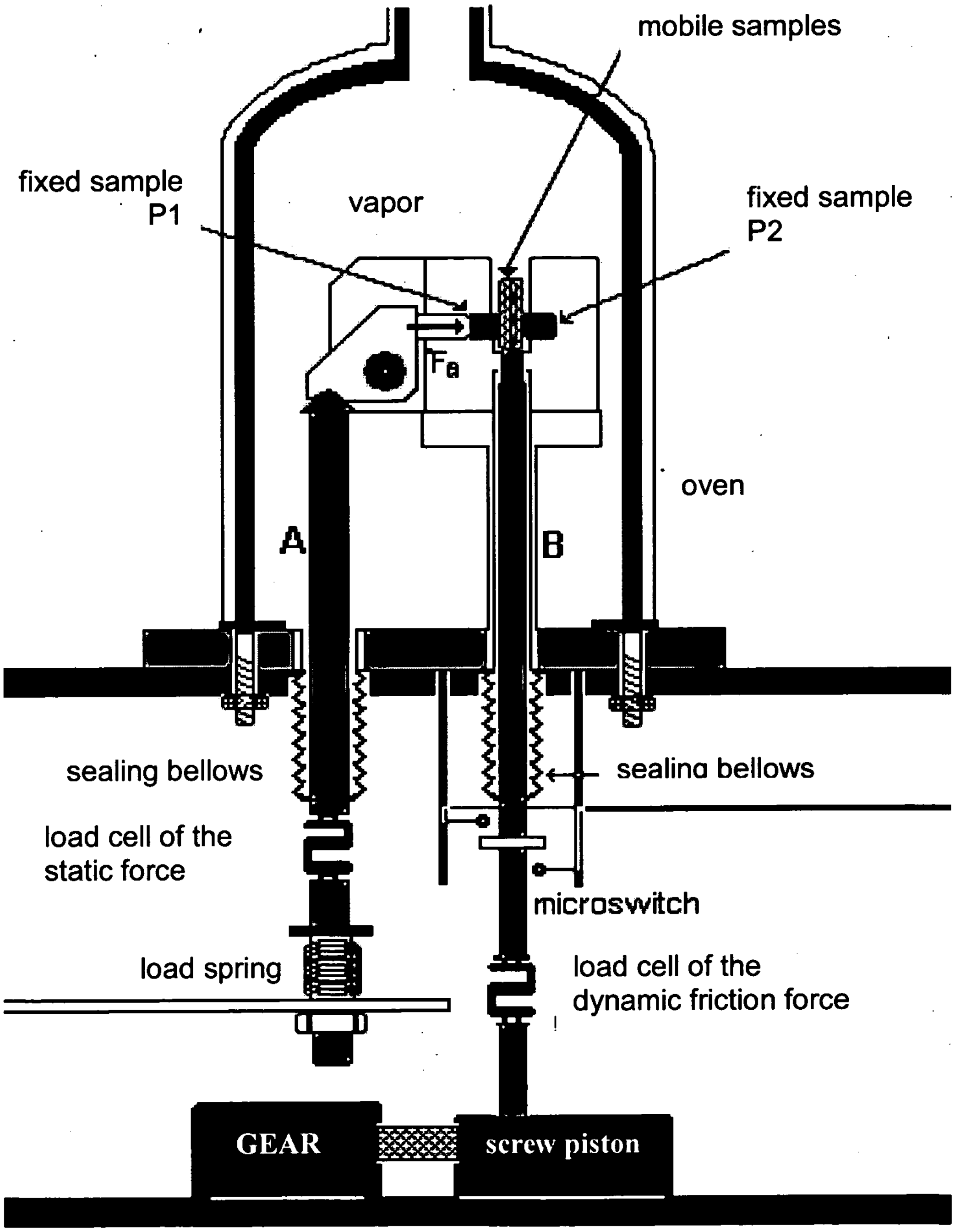
**19.** Powder according to the claims 15 to 18,
wherein the Co/Cr matrix represents 55-70 wt% of the coating and the $Cr_3C_2$ represents the 30-45 wt%.

**20.** Powder according to the claims 15 to 19,
wherein the Co/Cr matrix contains 70 to 95% of Co and 30 to 5% of Cr, preferably 90 to 95% of Co and 10 to 5% of Cr and represents the 55-65 wt% of the coating and the $Cr_3C_2$ represents the 35-45 wt%.

**21.** Powder according to the claims 15 to 20,
wherein the Co/Cr matrix and the chromium carbides are mechanically partially adhered.

**22.** Use of a powder according to the claims 15 to 21 in a coating process of a metallic product by thermal spray.

Fig. 1


mobile samples
fixed sample P1
vapor
fixed sample P2
Fa
oven
A
B
sealing bellows
sealina bellows
load cell of the static force
microswitch
load spring
load cell of the dynamic friction force
GEAR
screw piston

## Figure 2

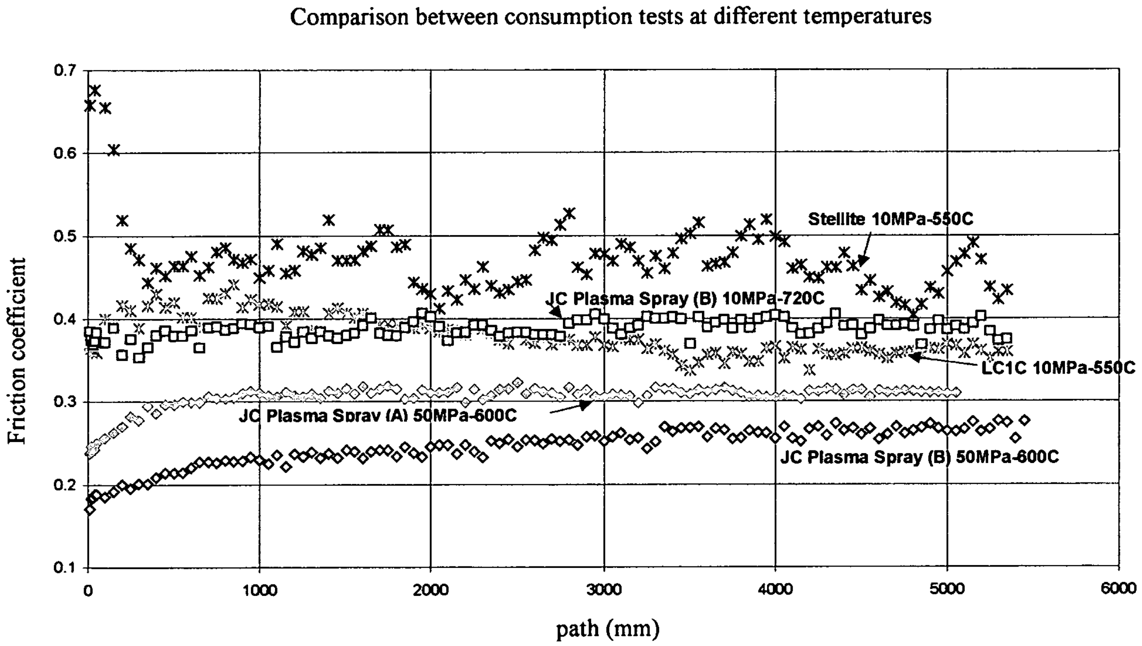

Comparison between consumption tests at different temperatures
Friction coefficient
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1000
2000
3000
4000
5000
6000
path (mm)
Stellite 10MPa-550C
JC Plasma Spray (B) 10MPa-720C
LC1C 10MPa-550C
JC Plasma Spray (A) 50MPa-600C
JC Plasma Spray (B) 50MPa-600C

Figure 3

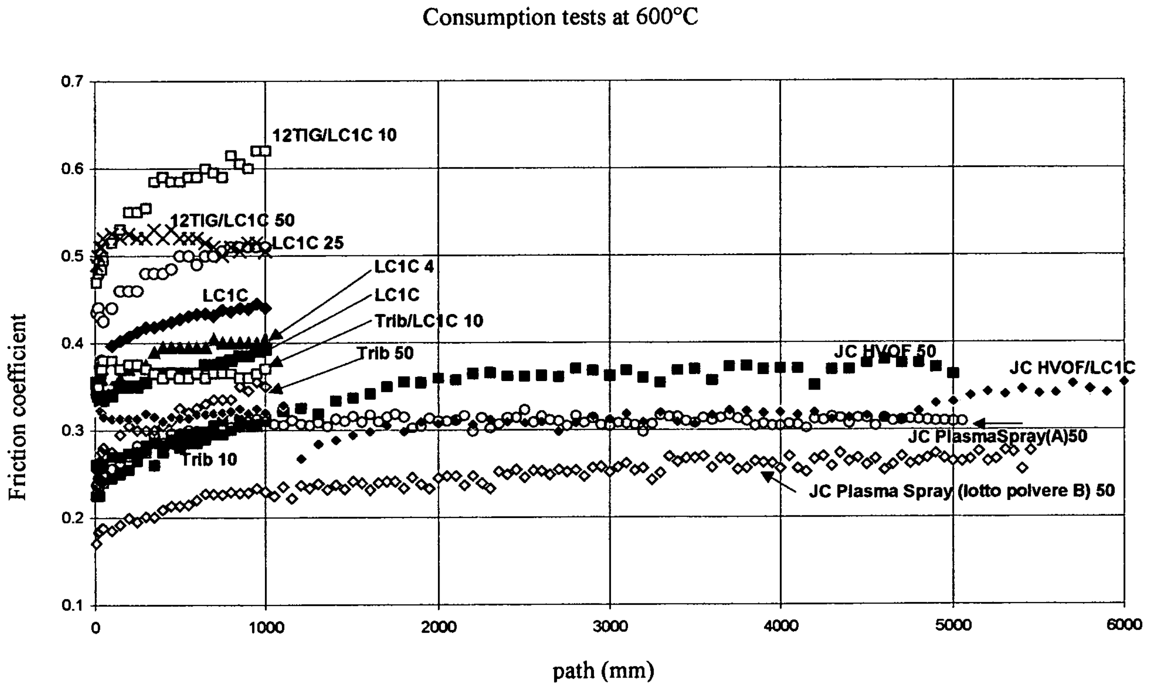
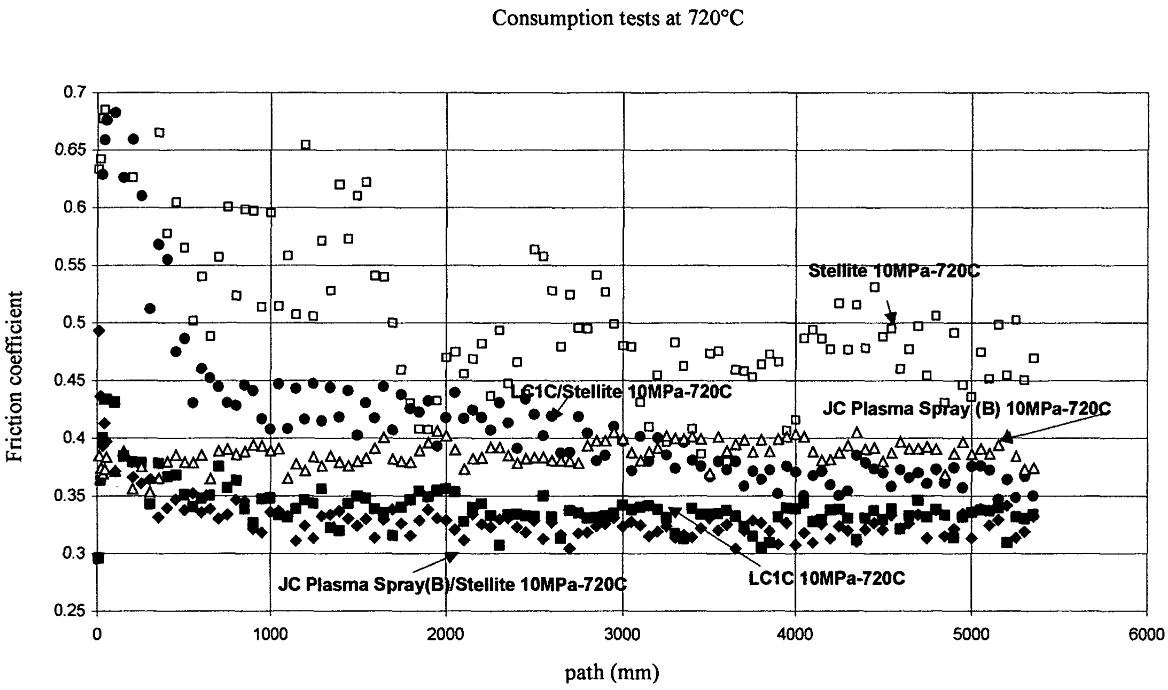
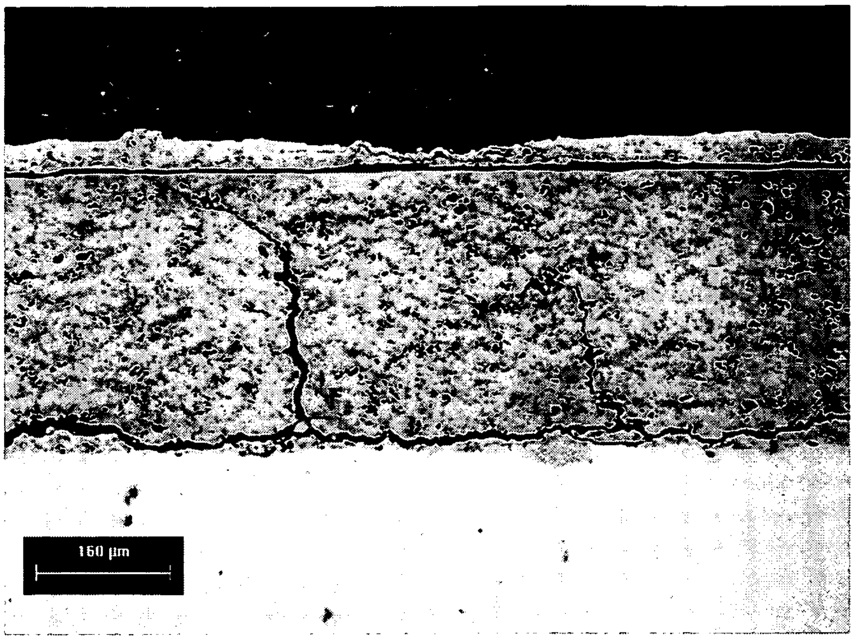

Consumption tests at 600°C
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Friction coefficient
0
1000
2000
3000
4000
5000
6000
path (mm)
12TIG/LC1C 10
12TIG/LC1C 50
LC1C 25
LC1C 4
LC1C
LC1C
Trib/LC1C 10
Trib 50
Trib 10
JC HVOF 50
JC HVOF/LC1C
JC PlasmaSpray(A)50
JC Plasma Spray (lotto polvere B) 50

Figure 4


Consumption tests at 720°C
Friction coefficient
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0
1000
2000
3000
4000
5000
6000
path (mm)
Stellite 10MPa-720C
LC1C/Stellite 10MPa-720C
JC Plasma Spray (B) 10MPa-720C
JC Plasma Spray(B)/Stellite 10MPa-720C
LC1C 10MPa-720C

## Figure 5



## Figure 6

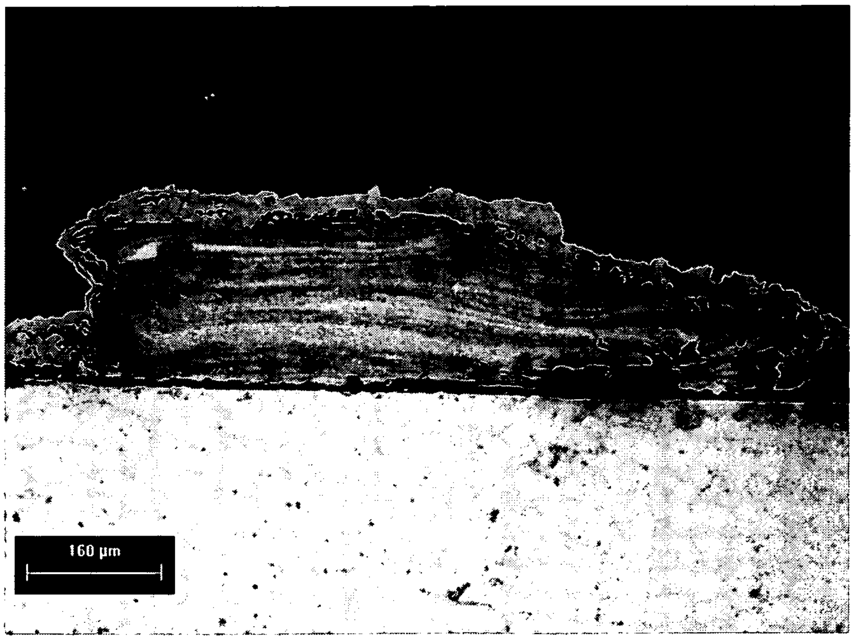


Figure 7

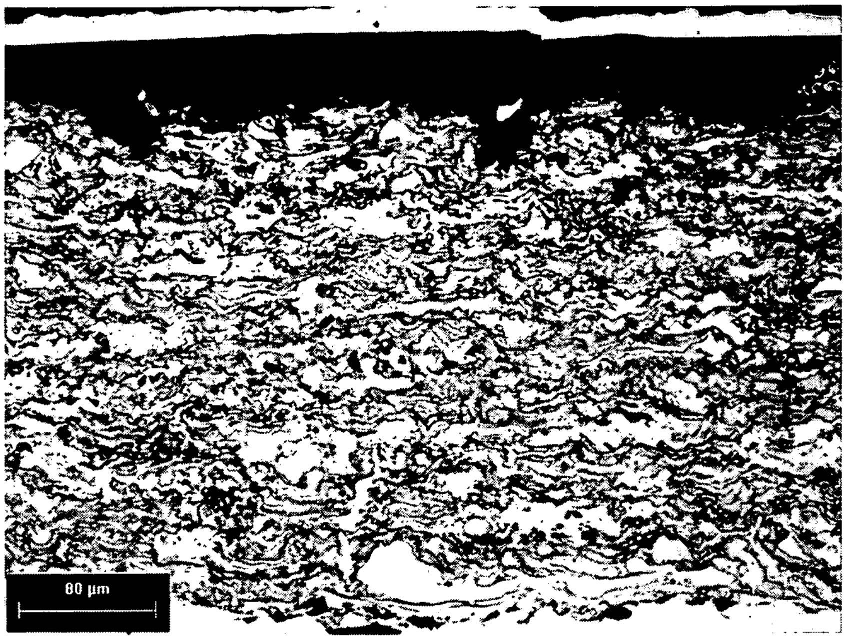
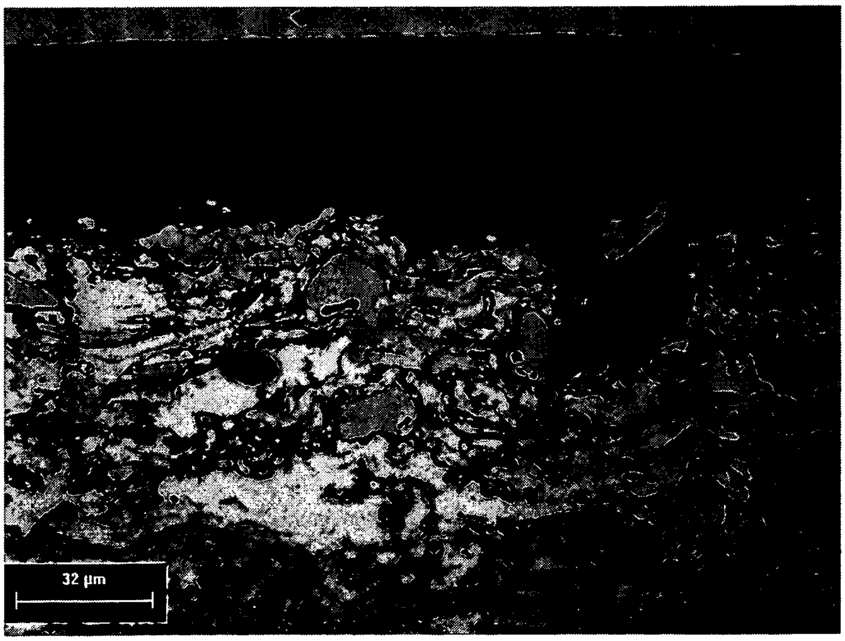


Figure 7.1



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Application Number
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The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| MUNICH | 28 April 2004 | Teppo, K-M |

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