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(54) **METHOD FOR REMOVAL OF CERAMIC COATINGS BY SOLID CO^2 BLASTING**

VERFAHREN ZUR ENTFERNUNG VON KERAMIKBESCHICHTUNGEN MIT EINEM STRAHLVERFAHREN MIT CO^2 IN FESTEM ZUSTAND

PROCÉDÉ POUR L'ENLÈVEMENT DE REVÊTEMENTS CÉRAMIQUES PAR DÉCAPAGE AU CO2 À L'ÉTAT SOLIDE

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EP 2 576 138 B2

Description

Background

[0001] The industrial market is focused on the optimization of the products quality and on the production and environmental costs reduction. In this contest the surface engineering has more and more importance because it enables to get better component performances only modifying the component surface. One of the main aspects of the surface engineering is the application of ceramic thick coatings and ceramic thin films. The thick coatings are defined as the protective layer with a thickness greater than 100 μm while the thin films are defined as protective layers with a thickness lower than 100 μm. Ceramic thick coatings are made by thermal spray technologies as Air Plasma Spray (APS), Vacuum Plasma Spray (VPS), Suspension Plasma Spray (SPS), Solution Precursor Plasma Spray (SPPS) and High Velocity Oxygen Fuel (HVOF), mainly. Ceramic Thin Films are applied by Chemical Vapor Deposition (CVD) and Physical Vapor Deposition (PVD), mainly.
Thick Ceramic Coatings are used for different application:

- Coatings to improve component wear resistance as Al_2O_3, Cr_2O_3, Al_2O_3-TiO_2, Al_2O_3-ZrO_2-TiO_2;
- Coatings to improve the component corrosion resistance as Al_2O_3, Al_2O_3-TiO_2, Cr_2O_3, ZrO_2-CaO;
- Alumina-based coatings to improve electrical insulation of a metallic component;
- Thermal Barrier Coatings are composite coatings systems. TBC systems consist of (i) a Bond Coat (BC) of MCrAlY alloy (where "M" can be Ni, Co or a combination of both) and (ii) a ceramic Top Coat (TC) of Yttria Partially Stabilized Zirconia (YPSZ). MCrAlY coatings are able to protect the substrates from high temperature oxidation and hot corrosion. Zirconia coating, for its low thermal conduction coefficient is able to reduce the service temperature at the substrate surface in combination with a cooling gas system. For these reasons TBC systems are applied on gas turbine hot parts. Usually, the specifications of the main OEMs (original equipment manufacturers) require the deposition of MCrAlY alloys by low pressure plasma spray (LPPS) or vacuum plasma spray (VPS). Other methods such as air plasma spray (APS) and high velocity oxygen fuel (HVOF) may be desirable for their lower cost. The thermally sprayed ceramic TC adhesion is mainly determined by the BC roughness that must have an Ra greater than 10 μm (about 12-16 μm) to guarantee a good thermal fatigue resistance during the component service life. Ceramic TC in YPSZ is applied on metallic BC by APS;
- Coatings to improve bio-compatibility of the metallic prosthesis based on TiO_2 and hydrossyapatite $Ca_{10}(PO_4)_6(OH)_2$.

Ceramic Thin Films are applied for different application:

- Thin films to modify optical properties of the component;
- Decorative thin films based of metallic nitrides and oxides;
- Thin films to improve wear and corrosion resistance of the components based on metallic nitrides, oxides and oxi-nitrides, mainly.

The ceramic coating removal is an important aspect in the production of coated components. "Decoating" or "stripping" is needed during the production of new components as well as for the reconditioning of existing ones:

(i) Stripping offers the possibility to correct problems of coating quality (thickness, porosity, roughness, adhesion, etc.) during the production steps;
(ii) During repair operations on serviced coated components, the removing of the ceramic layer is the first operation step;

The main characteristic of the stripping processes is to remove the coating without damaging the substrate characteristics (avoiding corrosion, geometrical variations, etc.). The Thermal Barrier Coating removal is a good example to understand the stripping process. The TC and/or BC stripping is necessary on new coated parts during MCrAlY or TBC manufacturing to correct problems of coating quality and during repair operations on serviced coated components. At the state of the art the removing of the TBC system is very time consuming and expensive: If it is necessary to remove only the ceramic TC, it is necessary to remove all the TBC using sand blasting to strip the ceramic top coat and chemical acid attack to remove the metallic MCrAlY BC. This procedure is necessary because sand blasting decreases bond coat roughness which is fundamental for TC adhesion. So, in the end, it is necessary to strip both the coatings to fix only the top coat. This leads to have very high re-work and environmental costs.

[0002] It would be desirable to have available a less costly and locally applicable process by which only the ceramic coating (i.e. Thermal Barrier Coating) can be purposefully removed without modifying the characteristics of the substrate such as roughness and thickness.

[0003] From the prior art, different methods for local removal of ceramic coatings are already known (see, for example, the publications US-A1-2005/0126001, US-A1-2004/0244910, WO-A1-02/103088, WO-A1-2005/083158, DE-A1-10 2004 009 757, US-A1-2004/0115447, US-A1-2004/0256504, US-A1-2003/0100242 and DE-B4-103 60 063). Other methods for local repair of coating systems are known from the publications US-A1-2002/0164417, DE-T2-601, 03 612, US-A1-2003/0101687, EP-A1-1 304 446, EP-A1-0 808 913 and US-B1-6, 235, 352.

[0004] The complete removal of Thermal Barrier Coating Systems, by means of chemical methods alone, or in combination with other methods, have been handled in a different way in the publications DE-A1-10 2004 049 825, US-A1-2001/0009246, US-A1-2001/0009247 and EP-B1-1 076 114.

[0005] Furthermore, it is known (Fr.-W. Bach et al., "Abtragen von thermisch gespritzten Schichten mit dem Trockeneis-Laserstrahl", GTS-Strahl Vol. 14, September 2004; Fr.-W. Bach et al., "Dry ice blasting and water jet processes for the removal of thermal sprayed coatings", Conf. Proc. ITSC 2005, Basle, p. 1542-1548 (2005)) to remove protective coatings, such as Thermal Barrier Coatings, which are on components, by means of a dry ice blasting process.

[0006] A possible faster and lower cost alternative to the state of the art of ceramic coatings removal is the Dry Ice CO_2 Stripping as described in a recent patent [US20080178907].

[0007] Dry-ice particle blasting is similar to sand blasting, plastic bead blasting, or soda blasting where a media is accelerated in a pressurized air stream (or other inert gas) to impact the surface to be cleaned or prepared. With dry-ice blasting, the media that impacts the surface is solid carbon dioxide (CO_2) particles. One unique aspect of using dry-ice particles as a blast media is that the particles sublimate (vaporize) upon impact with the surface. The combined impact energy dissipation and extremely rapid heat transfer between the pellet and the surface cause instantaneous sublimation of the solid CO_2 into a gas. The gas expands to nearly eight hundred times the volume of the particle in a few milliseconds in what is effectively a "micro-explosion" at the point of impact that aids the coating removal process. Because of the CO_2 vaporizing, the dry-ice blasting process does not generate any secondary waste. All that remains to be collected is the removed coating.

[0008] As with other blast media, the kinetic energy associated with dry-ice blasting is a function of the particle mass density and impact velocity. Since CO_2 particles have a relatively low density, the process relies on high particle velocities to achieve the needed impact energy. The high particle velocities are the result of supersonic propellant or air-stream velocities.

[0009] Unlike other blast media, the CO_2 particles have a very low temperature of -109°F (-78.5°C). This inherent low temperature gives the dry-ice blasting process unique thermodynamically induced surface mechanisms that affect the coating or contaminate in greater or lesser degrees, depending on coating type. Because of the temperature differential between the dry ice particles and the surface being treated, a phenomenon known as thermal shock can occur. As a material's temperature decreases, it becomes brittle, enabling the particle impact to break-up the coating and sever the chemical bond that is weakened by the lower temperature. The thermal gradient or differential between two dissimilar materials with different thermal expansion coefficients can serve to break the bond between the two materials. This thermal shock is most evident when blasting a nonmetallic coating or contaminate bonded to a metallic substrate.

[0010] For example, in the case of TBC stripping, Dry Ice stripping should enable the removal of ceramic TC without modifying the MCrAlY bond coat characteristics and mainly the surface morphology.

[0011] The state of the art of dry ice stripping developed in the previous cited patents offers a coating removal methods which risk to damage the substrate and suffer from low efficiency or very long term duration.

[0012] Another example of the prior art is the document WO01/66365 which discloses a coating removal system having a solid particle nozzle with a detector for detecting particle flow and associated method; in this document an apparatus is provided for removing a coating from a substrate, comprising a nozzle having an outlet and adapted to direct a particle stream therethrough at a predetermined flow rate, a signal source for emitting a signal capable of traversing the particle stream, and a signal sensor positioned to detect the signal emitted by the signal source once the signal has passed through the particle stream. The particle stream is directed from the outlet of the nozzle toward a coating on a substrate to remove the coating from the substrate.

[0013] Document US 2008 0178907 discloses a method according to the preamble of claim 1.

Summary of the invention

[0014] It is an object of the invention to show the limit of the actual applied methods to remove ceramic protective layers and to provide a method and an equipment for removing ceramic thick and thin coatings with high removal efficiency and without damaging the substrate.

[0015] This method does not include the step of predemaging the ceramic coating before removing the ceramic layer using dry ice blasting as included instead in the previous cited patent [US20080178907]. The predamaging using shot peening or another sand blasting method using abrasive media shows the risk to damage the substrate characteristics as roughness and thickness.

[0016] The only pre-heating is not able to pre-damage the ceramic coating. The authors tested different kind of pre-heating and quenching: pre-heating from 200°C to 1000°C and quenching in water or liquid nitrogen. The pre-heating alone or the combination of pre-heating and quenching are not able to pre-damage or to remove the ceramic coating as a TBC or to get faster the dry ice stripping process. The only thermal shock is not able to remove the ceramic coating. Dry Ice Blasting is not able to remove in a fast way the ceramic coatings treated with shot peening or/and pre-heating as indicate in the previous cited patent [US20080178907]. Only a combination of a pre-heating during or immediately before the solid CO_2 blasting can lead to a fast ceramic coating stripping. This method includes only pre-heating by irradiation performed during or immediately before the blasting with solid CO_2. This is due to the ceramic coating damage mechanism.

[0017] During impact of the dry ice grains, some of the kinetic energy due to the high velocity of the CO_2 pellets and thermal energy due to the component high temperature after pre-heating is converted into sublimation energy. The solid carbon dioxide sublimates to gas growing the volume by a factor of up to hundreds. The fast sublimation of the solid CO_2 creates powerful shock waves which shot the protective coating surface and creates cracks and removes particles of the protective coating which are already blasted off, or which have only poor adhesion to the coating.

[0018] This effect decreases in function of the coating/substrate temperature up to the quenching. In fact starting, for example, from room temperature, the TBC removing speed is very slow. So the pre-damaging is not useful. The dry ice stripping method developed in this invention takes care of all the parameters involved in the stripping mechanism.

[0019] The density of the solid CO_2 pellets is proportional to the shock wave power. The more the pellets are dense, the more the gas volume growing during the sublimation is greater, the more the shock wave is stronger. The equipment used in this invention is able to maintain high the density of the CO_2 pellets sudden out of the spray gun nozzle.

[0020] The mass flow of the solid CO_2 pellets is proportional to the shock wave power. The more the amount of Dry Ice pellets interact with the coating surface subliming, the stronger is the shock wave. The higher is the gas pressure transporting the solid CO_2 pellets, the higher is the removal rate. In fact the gas pressure helps the removal of the fragments from the fragmented ceramic coating after the impact of the shock waves. The higher is the gas pressure transporting the solid CO_2 pellets, the higher the solid CO_2 pellets mass flow can be.

[0021] At the state of the art blasting machines for dry ice can use only a discontinuous (pulsed) solid CO_2 blasting flow. This limits the removal rate because the stripping happens only when solid CO_2 sublimation is present and it is greater if the temperature of the substrate/coating is higher. If the mass flow is not constant the cool air gets the substrate/coating colder without generating the removal effect. This invention presents a sand blasting equipment able to have a continuous (not pulsed) solid CO_2 blasting flow (constant pressure). These optimized parameters with very fast pre-heating permit fast ceramic coating removal without damaging the characteristics of the substrate.

Brief description of the drawings

[0022] The invention is subsequently explained in more detail with reference to exemplary embodiments in conjunction with the drawings, in which:

- Figure 1 shows a scheme of the ceramic coating to be removed (Fig.1(2)) by means of blasting by solid CO_2 without damaging the substrate (Fig.1 (1)) characteristics where the coating is deposited. Substrate characteristics are thickness and roughness.
- Figure 2 shows in a plurality of sub-Figs. 2 (a) and 2(b) the two different how the pre-heating step is carried out during the solid CO_2 blasting (Fig.2 (a)) or immediately before (Fig.2 (b)); 3 schematizes the sand blasting gun during the stripping phase spraying the dry ice pellets schematized as 4. 5 schematizes the IR lamp used to obtain fast pre-heating of the substrate (1)/Coating (2) using IR radiation schematized as 6.

- Figure 3 schematized the Pre-Heating and Solid CO_2 Blasting Stations.
- Figure 4 schematized the Core of the Solid CO_2 pellets Feeder where stationary part are indicated by the motif 7 and the part in movement are indicated by the motif 8.
- Figure 5 shows the Scheme of the CO_2 Pellets Two-Hose Nozzle.

Detailed description

[0023] The present invention refers to a method and an equipment to remove ceramic protective coatings 2 (i.e. Thermal Barrier Coating such a Yttria Partially Stabilized Zirconia - YPSZ) with high removal efficiency and without damaging the substrate 1 characteristics.

[0024] The removing of the ceramic coating 2 without damaging the substrate 1 characteristics is obtained by a combination of coating/substrate pre-heating by irradiation immediately before (Fig.2 (b)) or during the stripping (Fig.2 (a)) and improved solid CO_2 4 blasting parameters. The substrate 1 can be metallic, ceramic, plastic or composite. The substrate characteristics not affected by the present invention are the substrate thickness and roughness. Substrate thickness can vary in an range of 1 μm to 1 m. The substrate can be rough (Ra > 9 μm) or smooth (Ra < 9 μm).

[0025] The stripping method is a single stage process where only a combination of a pre-heating during or immediately before the blasting with solid CO_2 4 can lead to the ceramic coating stripping. The equipment to remove ceramic protective coatings is divided in two parts: Pre-heating Station 5 and Sand Blasting Machine Station 20. This method does not include the step of pre-damaging the ceramic coating 2 before stripping step by dry ice blasting. The substrates 1 coated with ceramic coating 2 are pre-heated in sequence in the pre-heating stations 5 (Fig.3) up to the maximum temperature that the substrate can tolerate. The pre-heating station 5 is able to heat the coating/substrate up to a maximum temperature of 1000°C.

[0026] When the substrate/coating systems is arrived at the optimized temperature to obtain the maximum removing velocity, the coated component in moved in the solid CO_2 blasting station 20.

[0027] The coating stripping using solid CO_2 blasting with optimized parameters is performed up to the quenching of the process at room temperature.

[0028] The component is then moved in another pre-heating station 5 while another hot component is moved into the stripping station 20 (Fig.3). The steps of pre-heating and solid CO_2 blasting are repeated for each substrate up to the complete coating removal. The equipment can be made by n (N=1-100) pre-heating stations 5 and n sand blasting machine stations 20 (M = 1-50) (Fig.3).

[0029] The Sand Blasting Machine Station 20 for blasting by solid $CO_2$4 used in the method consists of a compressor, a feeder unit to feed dry ice into one or more spray guns 3. There are two general classes of blast machines as characterized by the method of transporting pellets to the nozzle: two-hose (suction design) and single-hose (pressure design) systems. In either system, proper selection of blast hose is important because of the low temperatures involved and the need to preserve particle integrity as the particles travel through the hose. In the two-hose system, dry-ice particles are delivered and metered by various mechanical means to the inlet end of a hose and are drawn through the hose to the nozzle by means of vacuum produced by an ejector-type nozzle. Inside the nozzle, a stream of compressed air (supplied by the second hose) is sent through a primary nozzle and expands as a high velocity jet confined inside a mixing tube. When flow areas are properly sized, this type of nozzle produces vacuum on the cavity around the primary jet and can therefore drag particles up through the ice hose and into the mixing tube where they are accelerated as the jet mixes with the entrained air/particle mixture. The exhaust Mach number from this type of nozzle is, in general, slightly supersonic. Advantages of this type of system are relative simplicity and lower material cost, along with an overall compact feeder system.

[0030] Blast machines are also differentiated into dry ice block shaver blasters and dry-ice pellet blasters. Pellet blast machines have a hopper that is filled with pre-manufactured CO_2 pellets.

[0031] The hopper uses mechanical agitation to move the pellets to the bottom of the hopper and into the feeder system.

[0032] The pellets are extruded through a die plate under great pressure.

[0033] This creates an extremely dense pellet for maximum impact energy.

[0034] The pellets are available in several sizes ranging from 0.040 inch (1 mm) to 0.120 inch (3 mm) in diameter. The 0.120 inch (3 mm) in diameter pellets are commercially available.

[0035] The solid CO_2 blasting machine station use a continuous (not pulsing) solid CO_2 blasting flow (constant pressure). Said continuous flow is obtained using a core in the feeder device (Figure 4) in combination with a spray two-hose nozzle gun 3 (Figure 5).

[0036] The Dry Ice is fed using a special feeding device as schematized in Figure 4.

[0037] The dry ice pellets contained in a box 9 are moved by a rotating scoop 10 in a large hole 11.

[0038] Then the dry ice pellets are moved from the position 11 by a rotating punched tool in a further hole in the position 12.

[0039] In this way the dry ice pellets 4 are continuously stocked in the feedstock area 12.

[0040] An air pressure flow (in a range of 1-5 bar) coming from 13 moves the pellets accumulated in 12 in the direction 14 up to the two-hose nozzle of the spray gun 3. The two-hose nozzle is schematized in Figure 5.

[0041] Solid CO_2 pellets are fed in the main nozzle hose 17 by axial injection 16 in the internal injector 18. A second pipe with high pressure air up to thirty bar is connected with the convergent/divergent nozzle 19 (Fig.5). The high pressure air is accelerated by convergent/divergent nozzle up to supersonic speed. The dry ice pellets 4 are injected directly in the accelerated high pressure air stream after the nozzle throat 19.

[0042] The continuous flow shows a mass flow of solid CO_2 4 in a range of about 100 - 3500 g/min and a pressure in a range of 1 - 30 bar.

[0043] A continuous flow of solid CO_2 is very important in order to reach very high removal rate. In fact if the flow is pulsed not only solid CO_2 will arrive on the coating surface but cool air, too.

[0044] The cool air will decrease the substrate/coating temperature without a contribution to the stripping process that is due to the shock waves due to the solid CO_2 sublimation. In that way the removal rate will be less than using a continuous flow of solid CO_2. High pressure is very important to increase the mass flow and to increase the removal rate. In fact, when the shock waves crumble ceramic coatings, the high pressure aids ceramic fragments removal.

[0045] The solid CO_2 Pellets used for blasting have very high density (Density 1.4 -1.6 g/cm^3). The CO_2 pellets density is very important because the more is the density, the more is the shock wave power due to the solid CO_2 sublimation.

[0046] The sand blasting equipment is designed to maintain the pellets density in a range of 1.525 - 1.6 g/cm^3 before the impact on the ceramic coating. This is obtained using in combination the above mentioned feeder and two-hose nozzle.

[0047] The pre-heating systems is performed by IR lamps 6 using irradiation.

[0048] This method shows two advantages:

- The irradiation with IR allows to perform the pre-heating during the solid CO_2 blasting;
- The irradiation with IR is able to heat the substrate/coating system up to 1000°C.

The heating speed depend on the nature of the substrate and it can be in a range of 1°C/min to 100°C/min. The pre-heating systems consist of IR lamps 6 in a range of wavelength of 1-10 μm and with a power output in a range of 1000 - 50000 W. The method as recited in claim 1 is able to remove a ceramic coating with a speed of 1 - 100 cm^2/min.

Claims

1. A method for removing ceramic coatings (2) applied on metallic, ceramic, plastic or composite substrates (1), comprising stripping by blasting phase with solid CO_2 (4) blasting; said method being applied without modifying or damaging the substrate (1) characteristics, thickness and roughness, and being able to prepare the substrate (1) to be recoated with a new ceramic layer (2) ; wherein it provides a combination of coating(2)/substrate(1) pre-heating by irradiation during or immediately before said stripping by blasting with solid CO_2 (4). **characterized in that** said components are pre-heated in sequence in the pre-heating stations (5) then the coating is stripped with solid CO2 (4) up to the quenching of the process, namely room temperature; the steps of pre-heating and solid CO2 blasting are repeated for each substrate up to the complete coating removal.

2. Method, as recited in claim 1, **characterized in that** apply a continuous, namely not pulsed, solid CO2 blasting flow.

3. Method, as recited in claim 2, **characterized in that** said solid CO2 blasting flow is applied with constant pressure.

4. Method, as recited in claim 1, **characterized in that** said coating/substrate pre-heating by irradiation applies with a speed in a range of 1°C/min to 100°C/min.

5. Method, as recited in claim 1, **characterized in that** said coating/substrate pre-heating by irradiation is increased up to 1000°C.

6. Method, as recited in claim 2, **characterized in that** said continuous flow applies a mass flow of solid CO2 in a range of about 100 - 3500 g/min.

7. Method, as recited in claim 2, **characterized in that** said continuous flow can vary the pressure in a range of 1 - 30 bar.

8. Method, as recited in claim 1, **characterized in that** is able to jet the solid CO_2 saving the pellets density in a range of 1.525 - 1.6 g/cm^3 before the impact on the ceramic coating.

9. Method, as recited in claim 1, **characterized in that** removes ceramic coating with a speed of 1 - 100 cm^2/min.

Patentansprüche

1. Verfahren zum Entfernen von keramischen Schichten (2), die auf Substraten (1) aus Metall, Keramik, Kunststoff oder Verbundwerkstoff bestehen, umfassend eine Abstreifeinrichtung durch eine Phase mit einem Beschuss mit festem CO2 (4); wobei das Verfahren ohne die Eigenschaften der Substrats (1), d.h. Dicke und Rauheit, zu ändern oder beschädigen, angewendet wird, wobei das Verfahren ausgelegt ist, um das zu beschichtende Substrat (1) mit einem neuen keramischen Schicht (2) vorzusehen; wobei das Verfahren stellt eine Kombination aus einer Beschichtung (2) und einen Vorwärmer (1) des Substrats durch Bestrahlung bereit, während oder unmittelbar vor dem Abstreifen durch Beschuss mit festem CO2 (4), **dadurch gekennzeichnet, dass** die besagten Teile nacheinander in den Vorwärmstationen (5) vorgeheizt werden, dann wird die Beschichtung mit festem CO2 (4) abgestreift, bis die Kühlung des Prozesses genau bis auf der Umgebungstemperatur vorgenommen ist; wobei die Schritte des Vorwärmens und Beschusses mit festem CO2 für jedes Substrat bis die vollständige Entfernung der Beschichtung, wiederholt werden.

2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** eine kontinuierliche Strömung des Beschusses von festen CO2 aufgetragen und gerade nicht gepulst wird.

3. Verfahren nach Anspruch 2, **dadurch gekennzeichnet, dass** die Strömung des Beschusses von festen CO2 mit einem konstanten Druck aufgebracht wird.

4. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** das besagte Vorwärmen der Beschichtung/des Substrats durch Bestrahlung mit einer Geschwindigkeit zwischen 1°C/min und 100°C/min durchgeführt wird.

5. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** das besagte Vorwärmen der Beschichtung/des Substrats durch Bestrahlung bis zu 1000°C erhöht wird.

6. Verfahren nach Anspruch 2, **dadurch gekennzeichnet, dass** die besagte kontinuierliche Strömung einen Massenstrom von festem CO2 zwischen etwa 100 und 3500 g/min anwendet.

7. Verfahren nach Anspruch 2, **dadurch gekenn-**

zeichnet, dass die besagte kontinuierliche Strömung den Druck zwischen 1 und 30 bar verändern kann.

8. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** es in der Lage ist, einen Strahl von festem CO2 zu erzeugen, wobei die Dichte der Pellets zwischen 1,525 und 1,6 g/cm^3 vor dem Aufprall auf der keramischen Beschichtung behalten wird.

9. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** die keramische Beschichtung mit einer Geschwindigkeit zwischen 1 und 100 cm^2/min entfernt wird.

Revendications

1. Procédé pour enlever des revêtements en céramique (2) appliqués sur des substrats (1) en métal, céramique, plastique ou composite, comprenant un moyen de décapage par une phase de bombardement avec du CO2 solide (4); ledit procédé étant appliqué sans changer ni endommager les caractéristiques d'épaisseur et de rugosité du substrat (1), le procédé étant configuré de manière à préparer le substrat (1) pour être couvert par une nouvelle couche de céramique (2); dans lequel le procédé prévoit une combinaison d'un revêtement (2) et d'un dispositif de préchauffage (1) du substrat par irradiation pendant ou immédiatement avant ledit décapage par bombardement avec du CO2 solide (4), **caractérisé en ce que** lesdits composants sont préchauffés dans la séquence de préchauffage dans les stations (5), puis le revêtement est enlevé par décapage du CO2 solide (4) jusqu'au refroidissement du processus, précisément jusqu'à la température ambiante; les opérations de bombardement et de préchauffage du CO2 solide sont répétées pour chaque substrat, jusqu'à l'élimination complète du revêtement.

2. Procédé selon la revendication 1, **caractérisé en ce qu'**il est appliqué à un écoulement continu de bombardement du CO2 solide, et précisément non pulsé.

3. Procédé selon la revendication 2, **caractérisé en ce que** ledit écoulement de bombardement du CO2 solide est appliqué avec une pression constante.

4. Procédé selon la revendication 1, **caractérisé en ce que** ledit préchauffage du revêtement/substrat par irradiation est appliqué à une vitesse comprise entre 1°C/ min et 100°C/min.

5. Procédé selon la revendication 1, **caractérisé en ce que** le préchauffage du revêtement/substrat par irradiation est augmenté jusqu'à 1000°C.

6. Procédé selon la revendication 2, **caractérisé en ce que** ledit écoulement continu applique un débit massique du CO2 solide compris entre environ 100 et 3500 g/min.

7. Procédé selon la revendication 2, **caractérisé en ce que** ledit écoulement continu peut faire varier la pression entre 1 et 30 bar.

8. Procédé selon la revendication 1, **caractérisé en ce qu'**il est capable de produire un jet de CO2 solide en préservant la densité des boulettes entre 1,525 et 1,6 g/cm^3 avant l'impact sur le revêtement céramique.

9. Procédé selon la revendication 1, **caractérisé en ce que** le revêtement céramique est retiré à une vitesse comprise entre 1 et 100 cm^2/min.

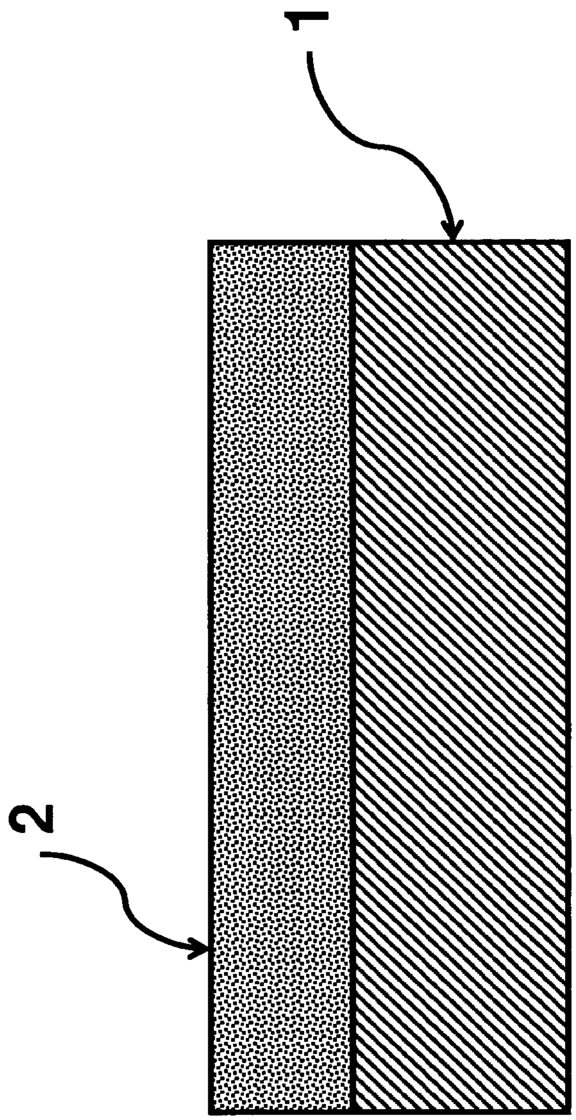

Figure 1

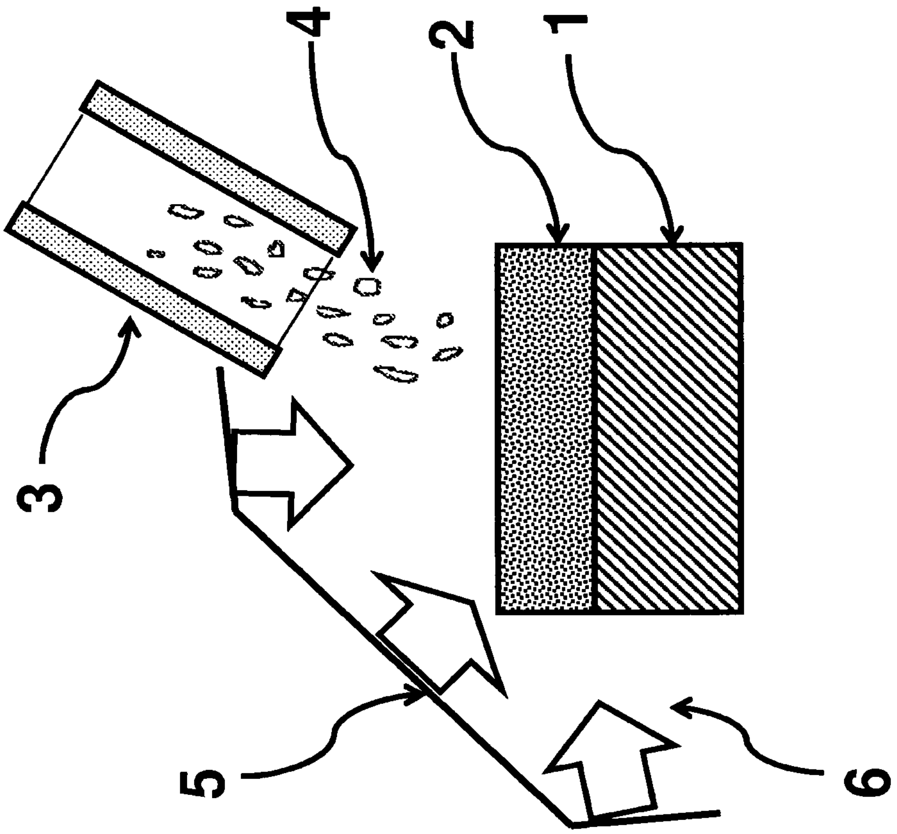

Figure 2 (a)

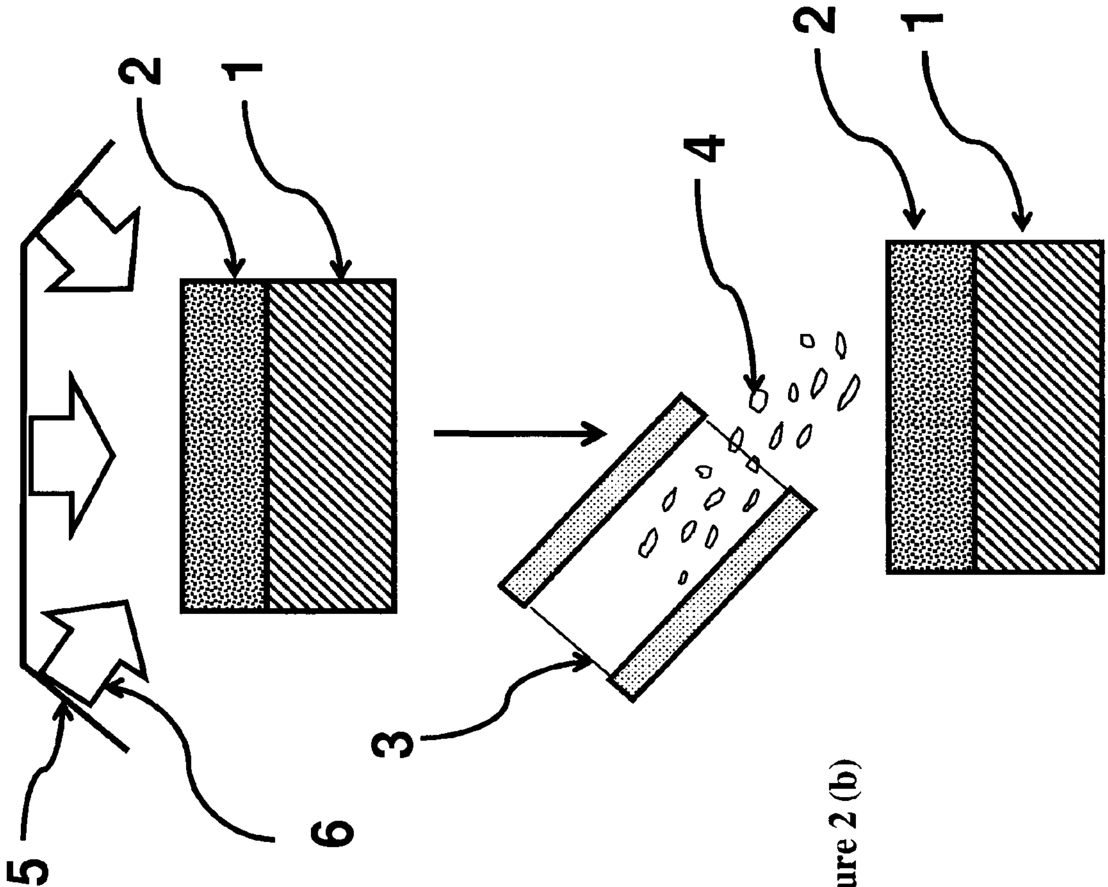

Figure 2 (b)

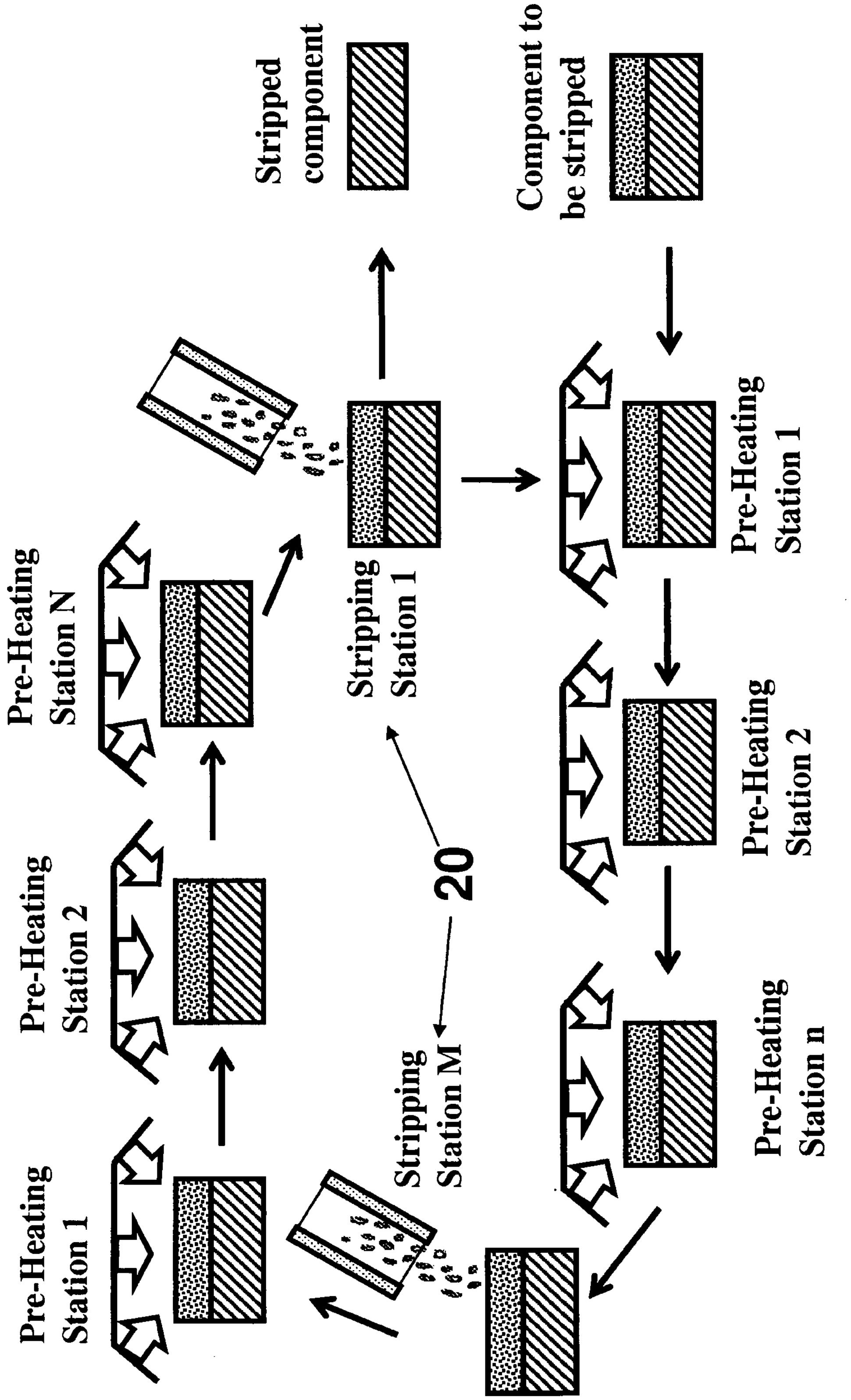
Stripped component
Component to be stripped
Pre-Heating Station N
Stripping Station 1
Pre-Heating Station 1
Pre-Heating Station 2
Pre-Heating Station 2
20
Pre-Heating Station 1
Stripping Station M
Pre-Heating Station n

Figure 3

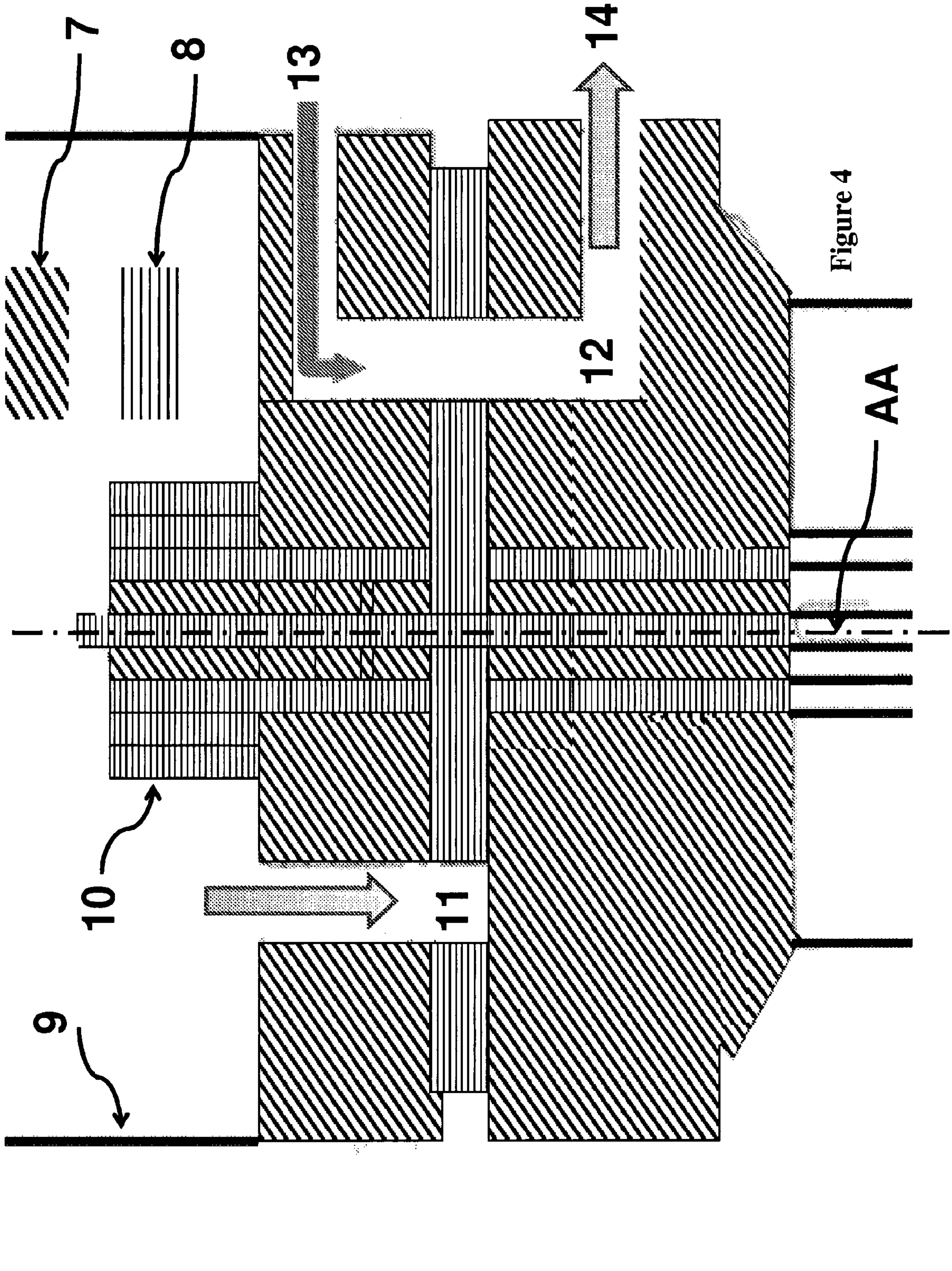

Figure 4

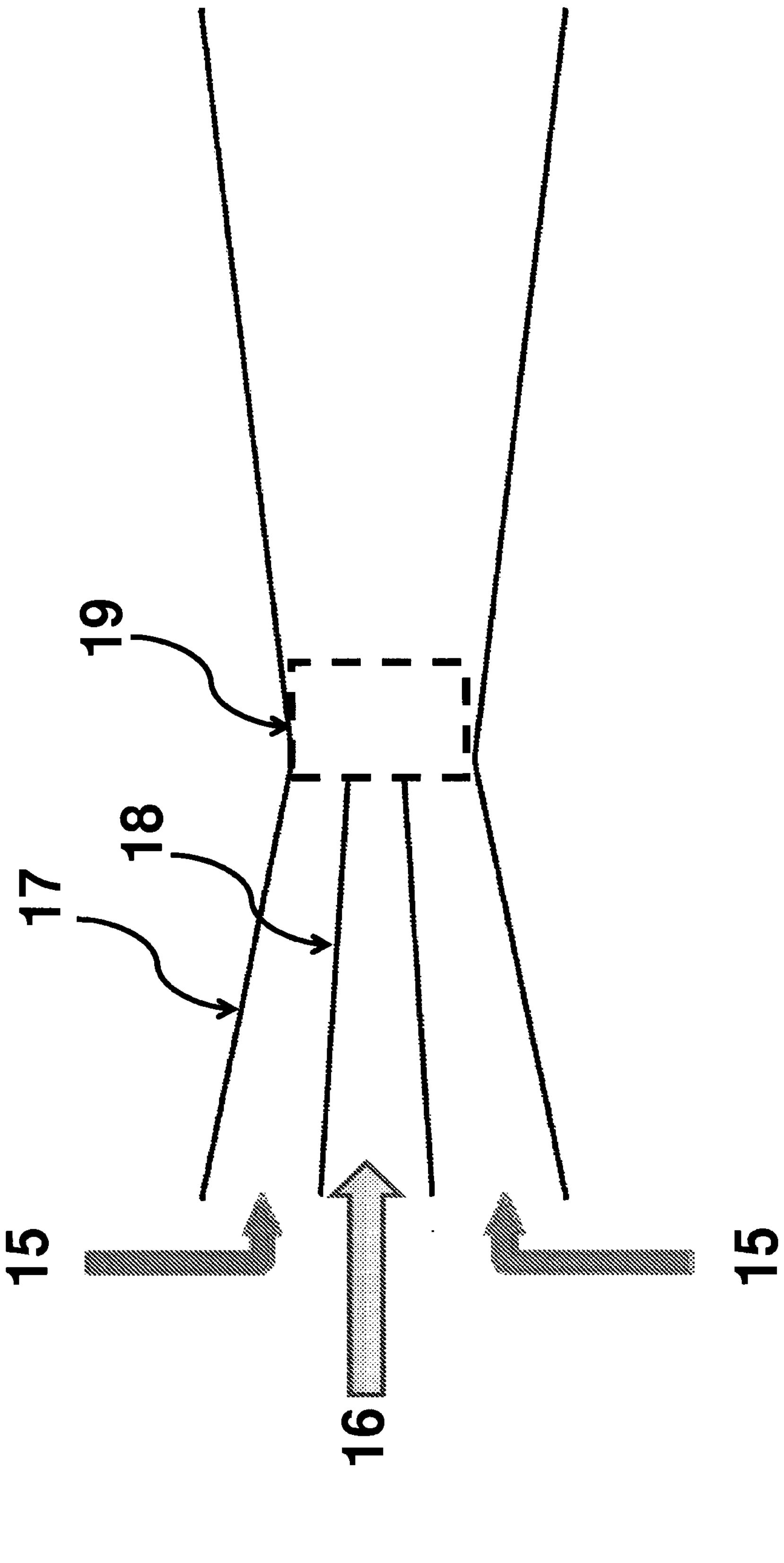

Figure 5

REFERENCES CITED IN THE DESCRIPTION

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