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(54) Method of repairing the coating of turbine blades

(57) Method for repairing a damaged protective coating (3) for gasturbine blades. The whole blade is masked, leaving only the damaged areas (2) free. The coating (3) is then completely removed from these areas

(2), either by chemical etching or by aluminium diffusion treatment. A new layer of protective coating (3) is then applied locally by plasma spraying.

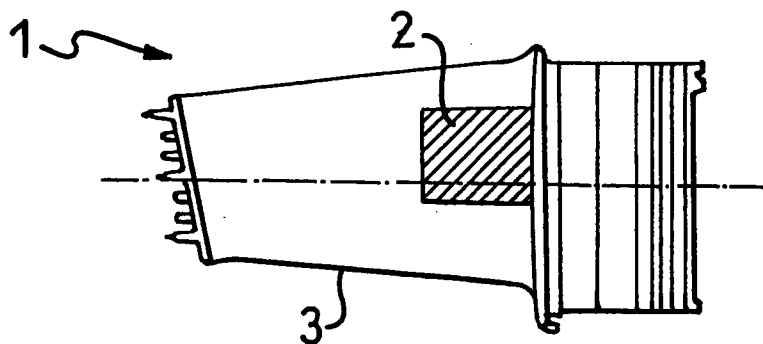


FIG.1

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Description

The invention relates to a method of repairing the coating of turbine blade produced by the deposition of drops of a protective material of the so-called MCrAlY type on a structure of base material of the Inconel type.

As is known, in the gas-turbine field, the blades referred to are subjected to particularly hard working conditions on account of the high-temperature and highly oxidizing and corrosive environments in which they are used; these blades, and it should be pointed out that this name also means, in general, both the rotor and stator blades of the turbine in question, are consequently produced by special techniques and with special materials.

In particular, it is known to coat the base material which forms the structure of the blade and is usually of the Inconel type, with a layer of highly resistant protective material.

In this connection, it is appropriate to point out that from a few years various techniques for the application of coatings have been developed and these can be divided, according to the method by which the protective material is transferred to the base material, into techniques for deposition at atomic level or in drops.

Without going into greater detail on this subject, for which reference can be made to specialized publications (for example: Metal Handbook, ninth edition, Vol. 5 by ASME - American Society of Mechanical Engineers), it should be pointed out that, in this description and in the following claims, reference will be made solely to coatings applied by the drop-deposition technique also known in the art by the English term "thermal spraying". Essentially, coating corresponding to this technique is carried out by the melting of the protective material, which is generally in powder form or in the form of a wire supplied by suitable equipment, and projecting drops thereof onto the surface to be protected, by means of an air or gas flow.

As regards the protective materials most commonly used, the class of powders known in the field as MCrAlY materials, should be mentioned; these are powders based on metals mixed with chromium, aluminium and yttrium, the chemical symbols of which (Cr, Al, Y) in fact form the word which defines them.

Moreover, the thermal energy for melting the material to be sprayed can be produced by the combustion of a gas, as in the case of so-called "flame spraying", or by the striking of an electric arc and, in this case, one speaks of "electric-arc spraying", or, finally, by an electric discharge which takes place in an ionized gas, as in the case of "plasma spraying". In order to carry out these operations, that is, to produce thermal energy and to direct gas or air in order to spray the molten material onto the surface to be coated, over the years, special devices, commonly known as torches, which can resist the very high temperatures involved, have been developed; furthermore, to improve the finishing of the coating and the quality of the work in general, the practice of carrying out

the coating in an atmosphere under vacuum or protected by inert gas has recently been introduced.

In spite of the technological advances made in relation to the materials, the equipment and to the methods referred to above, the application of coatings to turbine blades nevertheless involves considerable difficulties in execution and requires very accurate working. Indeed, for the protective coatings to be able to perform their functions at best, they must be applied homogeneously to the surface to be coated, which is not always easy to achieve; at the production stage, for example, surface defects, which may consist of reduced thickness of the coating or the presence of impurities or extraneous particles therein, are not infrequently found.

Even if they are present only locally, these defects constitute a point of attack in the coating and inevitably lead to generalized deterioration of the blade because of the extremely aggressive conditions already mentioned, in which they are used.

In other words, the presence of defects in the coatings of gas turbine blades unacceptably reduces their degree of reliability and their life, consequently leading to an increased probability of a breakage thereof with notably harmful consequences; indeed, these breakages may give rise to accidents at power-generating plants or to malfunctioning thereof, with adverse consequences which can easily be imagined. Moreover, it must be underlined that, on account of the materials used and of the sophisticated techniques referred to above for their manufacturing, the blades considered herein have very high production costs; any defect which reduces their degree of reliability and operating life therefore implies, in industrial practice, their declassing as products of inferior quality and therefore with a low sale price, also causing considerable damage from an economic point of view.

Moreover, it just matters to point out that considerations equivalent to those set out hitherto are also valid, with the necessary changes, in the case of any defect in the coating which occurs during the operation of the turbine because of the impact of particles against the blades.

It can therefore be understood that the need to repair the coatings of the blades effectively and safely is quite considerable, and so much the more if one considers the fact that, at the moment, when a defect is found in the coating, even if only locally, it is preferred to remove the entire coating and re-apply it entirely as new, with clear cost problems and without in any case being absolutely certain of achieving an optimal result.

The technical problem underlying the invention is that of devising a method of repairing the coatings of turbine blades produced by the deposition of drops of a protective material of the so-called MCrAlY type.

This problem is solved, according to the invention, by a method, the characteristics of which are set out in the first of the claims following this description.

Further characteristics and the advantages of the invention will be described below with reference to an

embodiment thereof, given by way of non-limiting example, with reference to the appended drawings, in which:

Figure 1 shows a gas-turbine blade upon which to carry out the method of the invention,

Figure 2 shows a torch for the deposition of drops which is used to carry out the method according to the invention,

Figure 3 shows a detail of the blade of Figure 1 during a stage of the method,

Figure 4 is a graph showing two variables which affect a stage of the method according to the invention,

Figures 5 and 6 show the detail of Figure 3 in successive operative stages of the method.

With reference to the drawings just described, a rotor blade for a gas turbine, indicated 1 therein, has a structure 1a made of Inconel IN738 base material (for the exact composition of the material identified by this name see, for example, the German standard TLV9560.03), with a damaged region 2 thereon shown by hatching where a repair is to be carried out with the method of the invention.

More precisely, the blade 1 has a protective coating 3 of the type which is applied by deposition of drops carried out under vacuum and with the use of plasma; this technique is also known by the name VPS which represents the abbreviation of the English words "vacuum plasma spray". Moreover, in this example, the coating material is of the type already mentioned above, known as MCrAlY, which is constituted by a powder with the following composition:

Co 31.8; Ni 31.4; Cr 27.8; Al 7.6; Y 0.7; Si 0.7;

and the thickness applied is between 170 and 300 μm . The hatched region 2 therefore relates to a damaged region of the coating 3.

The steps of the method to which the turbine blade just referred to was subjected, will now be described.

First step: removal of the original coating from the damaged region.

This step was carried out by two possible alternative operative techniques, the selection thereof depending essentially on the position and shape of the defect found; both will be described briefly below.

The first technique consists of a chemical etching cycle preceded at first by a sand-blasting treatment of the damaged region 2 to increase roughness and thus favour the etching effect; moreover, the surface of the blade not concerned by the repair was protected with the usual varnishes suitable for this purpose. The blade thus prepared was then immersed in a solution, at 70°C, of one litre of hydrochloric acid (HCl) diluted to 35% and

containing 5 gr (equal to 0.5% by weight) of a fluorinated compound to activate the chemical etching constituted, in this example, by a product known commercially as ACTANE 70.

In order to achieve a uniform chemical action, the bath in which the blade is placed was kept under agitation and the permanency time of the blade in the acid solution was about 3 hours. It should be pointed out, however, that this time spent depends upon the thickness of the coating to be removed, upon its composition and, possibly, upon the position of the damaged region and may therefore vary from case to case.

To determine the extent to which the coating had been removed from the damaged region, a test was then carried out thereon; this test was carried out by introducing the blade into an air furnace at a temperature of 650°C for about 20 minutes. As it cools, the region of the blade from which the coating has been removed assumes a colour which may be uniform blue or golden yellow: in the first case, this means that the coating has been completely removed, whereas in the second case, however, it indicates the need to repeat the immersion in the acid solution to remove residual portions of the coating.

In this latter case, the time spent will naturally be shorter than previously and can be calculated in dependence on the thickness still to be removed which can be detected by micrographic observations.

The second operative technique used to carry out the first step of the method of this invention provides for a treatment for the diffusion of aluminium on the region to be repaired.

More precisely, after undergoing the preliminary sand-blasting already described for the case of chemical etching, the surface of the blade was protected with masking 4 (see Figure 3) around the damaged region, by the application of an adhesive tape 5; the masking was constituted essentially by a piece of sheet metal disposed at a distance of about 2-3 mm from the coating 3 and a layer of aluminium 6 was then applied to the blade thus prepared, by the deposition of drops with plasma technique of the type already referred to above, for a thickness of 0.12-0.16 mm.

The blade was then brought to the solubilization temperature of the base material which, in the case in question, for the material IN738, is 1120°C, in a muffle furnace and in an inert-gas atmosphere; more precisely, the time spent by the blade at the solubilization temperature and, in general, the heating cycle to which it was subjected is illustrated in Figure 4; it can be inferred from this that, in general, after the blade had been brought to the solubilization temperature, the heating cycle provided for the blade to remain at that temperature for at least one hour, plus a further hour for each tenth of a millimetre of coating to be removed.

This treatment allows the aluminium to diffuse into the coating 3 causing it to become fragile locally, facilitating its subsequent removal as a result of a sand-blasting step to be carried out after the heating in the furnace.

After the sand-blasting it was then possible to determine the degree of removal of the coating in exactly the same way as already described for the case of chemical etching; naturally, in the event of insufficient removal, the steps just described should then be repeated.

Second step: deposition of a new protective coating in the damaged region.

The region 2 subjected to the first step of the method is then ready for the local application of a new layer of coating; in the embodiment carried out, this application was preceded by cleaning and preparation of a substantially frustoconical seat 10 in the region 2 where the coating had been removed and in the neighbouring regions, so that the new coating could be superimposed gradually on the previous coating (see Figure 5). This cleaning and preparation were carried out by further sand-blasting but it could have also been achieved by another equivalent working technique. The plasma technique was selected for the local application of the new layer of coating by the deposition of drops and was carried out in an atmosphere protected by inert gas with a torch 20 shown in Figure 2; this torch comprises a substantially frustoconical body 21 in which there is a space 22 for the circulation of cooling water which is supplied from an inlet 22a and expelled from an outlet 22b.

Moreover, a cathode 23 disposed on the axis of the body 21 extends in a duct 24a for the discharge of the plasma from a nozzle 24 of the torch; furthermore, the torch has a conveying structure 25 comprising an essentially cylindrical wall 25a fitted coaxially on the body 21 and fixed thereto.

This structure includes an annular chamber 26 into which inert gas is supplied through an inlet 26a which communicates with the interior of the structure by means of holes 27; these holes are disposed near the wall for the reasons which will become clearer from the following. Furthermore, an injector 29 extends adjacent the nozzle 24 for supplying material to be deposited on the surface to be coated which, in this case, is powder of the MCrAlY type with the composition already given.

The operating parameters of the torch described above are the flow-rate of argon and of hydrogen, as well as the current necessary for ionizing the gas and the distance at which the torch is kept from the surface of the blade; these depend, in general, on the operating region. In the example, the flow-rate of argon was 625 slpm (standard litres per minute), the flow-rate of hydrogen was 14 slpm, the electric current was 600 A and the distance of the torch from the blade was about 110 mm.

During the application of the coating material, the inert gas is introduced into the annular chamber 26 through the inlet opening 26a and reaches the interior of the conveying structure through the holes 27; by virtue of the distribution of the holes 27 near the walls, the inert gas is distributed coaxially around the plasma jet discharged from the nozzle, isolating it from the exterior and

protecting the deposit of drops of molten material on the surface, preventing possible oxidation of the region 2.

Moreover, the use of circular passes of the torch with gradually increasing diameters until the configuration of Figure 6 was reached, was found to contribute considerably to the achievement of an optimal result.

After the deposition of the new coating thus effected, the blade was subjected to a heat treatment to diffuse the material deposited by the torch; this treatment was carried out in a furnace with a chamber under vacuum to avoid the dangers of oxidation of the blade, with a heating cycle in which, first of all, the solubilization temperature of the base material (1120°C in the case of IN738) was reached with increments of 10°C per minute and then, after remaining at this temperature for 4 hours, the whole blade was brought back to 540°C with a progressive decrease of 20-40°C per minute and then to ambient temperature, with the admission of inert gas to the chamber of the furnace.

The blade repaired as just described was then subjected to surface finishing to bring its geometrical characteristics and roughness back within the limits required by the characteristics for gas-turbine applications.

Furthermore, non-destructive tests were carried out by means of ultra-sound to check for the presence of any detachment between the material applied and the original coating. These tests confirmed that the results achieved by the repair method of the invention are of considerable significance.

The blades which were subjected to this method in fact showed a degree of adhesion of the new material applied in the repaired region which was completely satisfactory and such as to confer on the blade an optimal degree of reliability in operation.

By virtue of the techniques used in the first step for the local removal of the layer of damaged coating, the operating region was cleared without alteration of the structure of the base material of the blade; this enabled the new coating subsequently deposited for the repair to adhere locally to the base material mentioned in substantially the same way as the original coating adhered to the blade during production.

Moreover, the application of the material by the plasma technique with protection by inert gas carried out with a torch permits quick and relatively inexpensive processing which is very suitable for the localized application necessary for the carrying out of this method.

Finally, the diffusion of the protective material deposited also helps to achieve a better result particularly as regards the final adhesion of the new material deposited to the base material of the blade.

As regards the advantages pertaining to the economical aspects of the method, in fact it should be pointed out that the repair of a blade by the method described can be carried out off line and therefore without using resources intended for production, for example, by mounting the torch on a mechanical arm, preferably of the type with programmable electronic control means, but without the use of vacuum chambers or other com-

plex equipment. In fact, the inert gas of the torch itself can protect the deposit of material, avoiding the danger of oxidation and, since the blade on which the repair is carried out is already coated with the original protective material in the regions surrounding the operating region, there is no risk of oxidation of these, in spite of the high temperatures involved, to which they are also subjected.

Finally, variants of the invention with respect to the example described above should not be excluded.

In fact, it should be pointed out that the repair method has also been carried out on blades of Inconel IN939 base material (again for the exact composition of this material see, for example, German standard TLV9561.04) and, more generally, with base materials of Ni, with 15-22% of Cr, 8-18% of Co, and 1.7-3.3% of Al. Furthermore, as regards the composition of the powders, it is also possible to use solutions based on Co with 30-35% of Ni, 20-30% of Cr, 5-13% of Al, and other elements in smaller percentages. As a result of the foregoing, in the case of a blade of IN939 base material, the solubilization temperature of this material is 1160°C and it has been found that, in general, the time spent at the solubilization temperature in the aluminium diffusion attack cycle, calculated on the basis of the graph of Figure 4, may vary in the region of about 10 minutes.

Finally, the values of the other parameters of the method (temperature, times, etc.) given in the preceding example may vary within a range which will depend, from case to case, upon the base material used, upon the position of the damaged region on the blade, upon the composition of the coating, etc. etc.

Claims

1. A method of repairing a turbine blade coating (3) produced by the deposition of drops of a protective material of the so-called MCrAlY type on a structure (1a) of base material of the Inconel type, characterized in that it comprises the following operative steps in succession:
 - removing the coating from the blade locally in the region to be repaired;
 - applying a protective material identical to that of the original coating locally in the region to be repaired by deposition of drops with plasma technique and with protection of inert gas.
2. A method according to Claim 1, characterized in that the step of removing the coating from a blade locally in the region to be repaired comprises chemical etching carried out with a solution of hydrochloric acid and a fluorinated compound for activating the chemical etching.
3. A method according to Claim 1, characterized in that the step of removing the coating locally in the region to be repaired comprises an aluminium diffusion treatment in which, first of all, drops of aluminium are deposited by plasma technique, and then a heating cycle is carried out in a furnace with an inert gas atmosphere, in which the blade is brought to the solubilization temperature of the base material.
4. A method according to Claim 3, characterized in that, during the heating cycle, the blade is kept at the solubilization temperature for a period of time of approximately one hour, plus one hour for each tenth of a millimetre of coating to be removed.
5. A method according to any one of the preceding claims, characterized in that it comprises, after the step of removing the coating, a test step to determine the quantity of protective material removed, carried out in an air furnace in the following manner:
 - heating the blade to a temperature of around 650°C for about 20 minutes;
 - detecting the colour of the region previously subjected to removal, after this heating, the colour being substantially blue when the coating has been completely removed.
6. A method according to any one of the preceding claims, characterized in that, before the step of the local application of the protective material, a substantially frustoconical seat (10) for receiving the material is formed in the region to be repaired and in the neighbouring regions.
7. A method according to Claim 2, characterized in that the chemical etching is carried out, after the undamaged surface of the blade has been coated with a protective varnish, by leaving the blade to soak in the solution which is heated to about 70°C.
8. A method according to any one of the preceding claims, characterized in that it comprises, after the local application of the protective material, a step to diffuse said material, which is achieved by heat treatment carried out in a furnace under vacuum in the following manner:
 - bringing the blade to the solubilization temperature of the base material with temperature increments of about 10°C per minute;
 - keeping the blade at that temperature for about 4 hours;
 - bringing the blade to a temperature of about 540°C with a reduction in temperature of 20-40°C per minute.
9. A method according to any one of the preceding claims, characterized in that said material of the

Inconel comprises materials which have a basic composition of Ni with 15-22% of Cr, 8-18% of Co, and 1.7-3.3% of Al.

10. A method according to any one of the preceding claims, characterized in that the protective material of the so-called as MCrAlY type comprises materials which have a basic composition of Co, with 30-35% of Ni, 20-30% of Cr, and 5-13% of Al.
11. A torch for applying protective material in a method according to any one of the preceding claims, characterized in that it comprises a body (21) on which there is fitted a structure (25) for conveying the plasma, including a substantially cylindrical wall (25a) coaxial with the body and extending in correspondence of a nozzle (24) thereof, the structure also including an annular chamber (26) coaxial therewith, provided with an inlet (26a) for the supply of inert gas and a plurality of holes (27) distributed peripherally near the wall.

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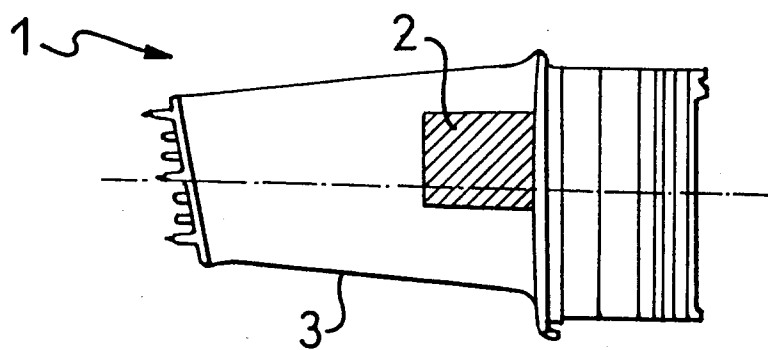


FIG. 1

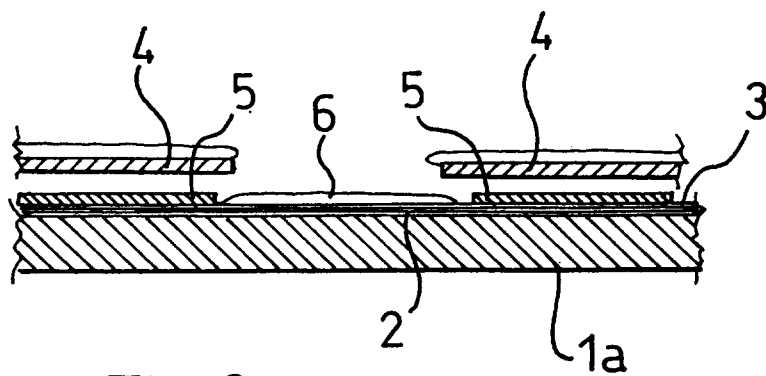


FIG. 3

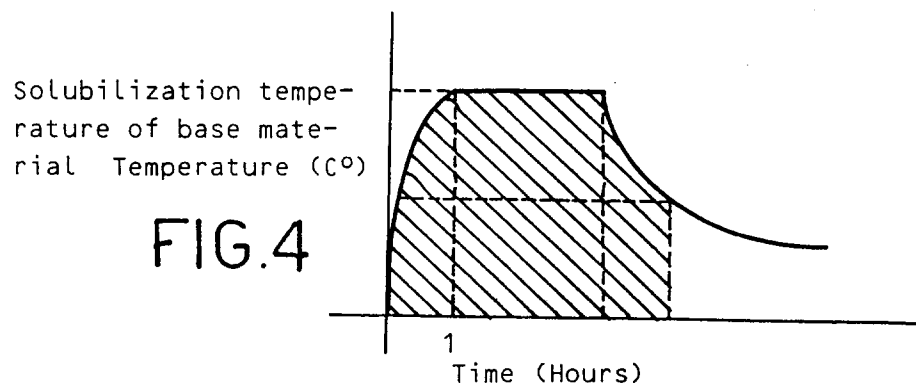


FIG. 4

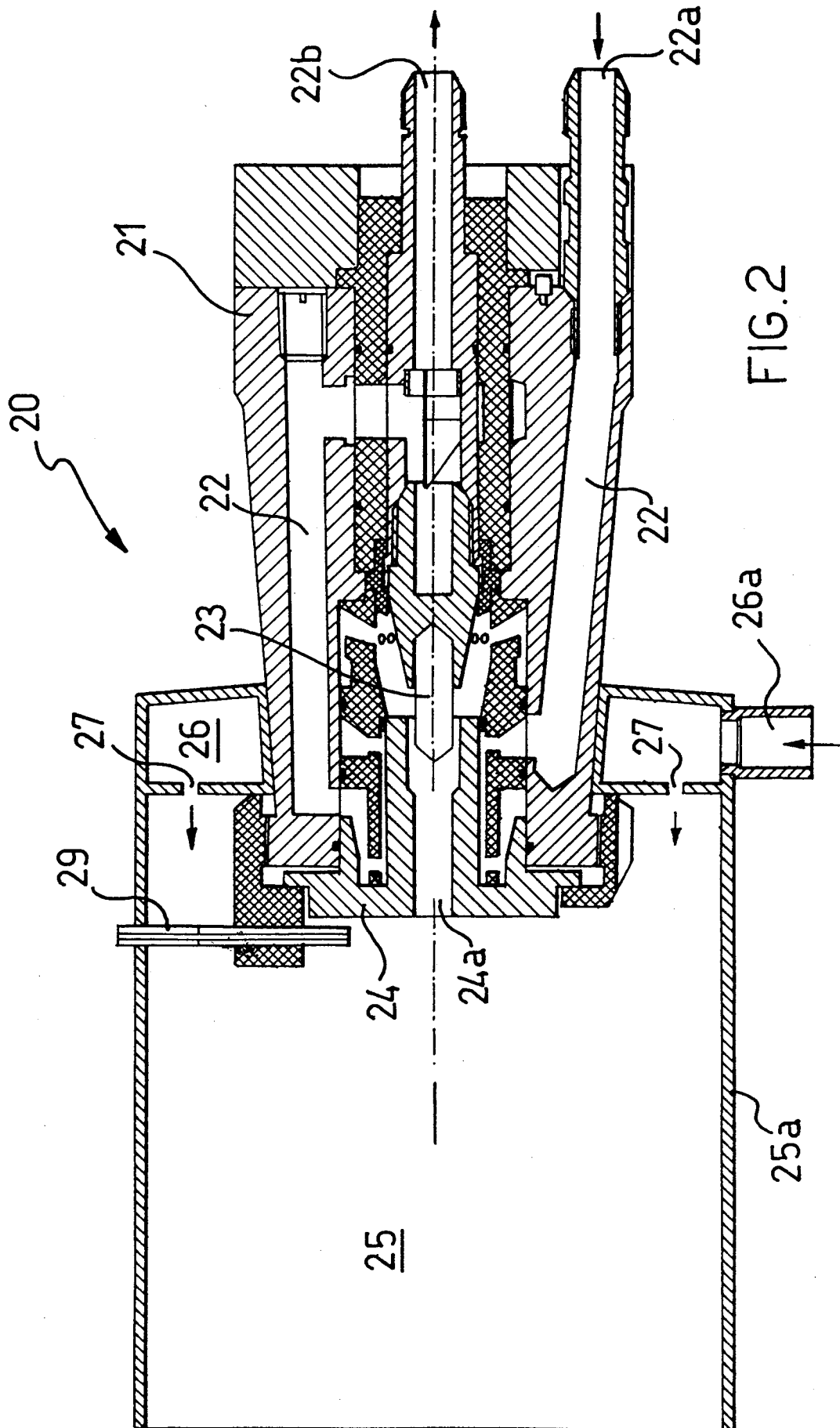


FIG. 2

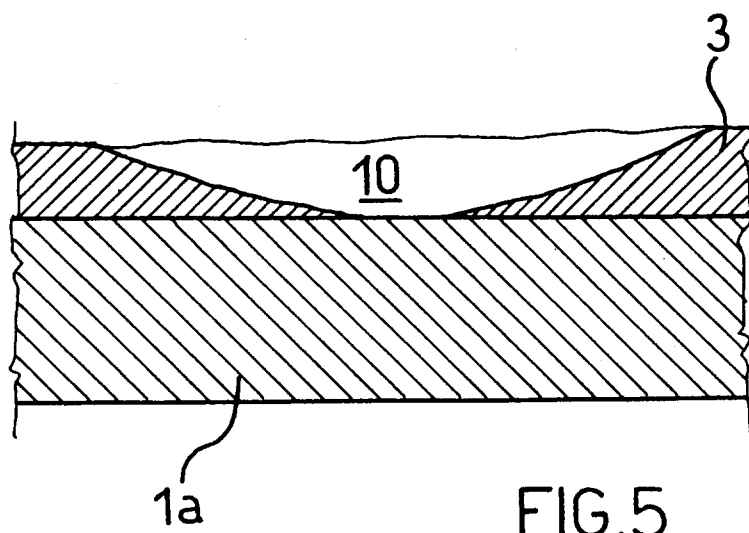


FIG.5

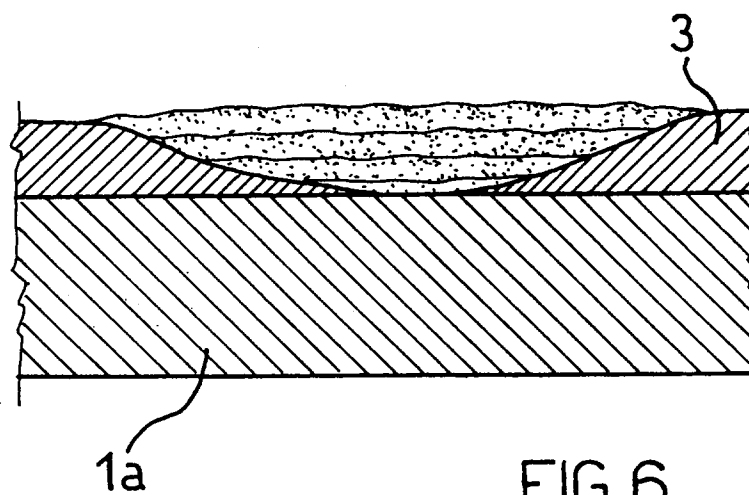


FIG.6

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EUROPEAN SEARCH REPORT

Application Number
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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	DE-A-43 03 137 (MTU) 11 August 1994 -----		
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 11 May 1995	Examiner Iverus, D
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