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(54) Low energy plasma coating

(57) A method of coating an aluminum alloy or magnesium alloy component, including cleaning and drying surfaces of the component to be coated; suspending a powdered coating material in a carrier gas and feeding the suspended powdered coating material through a plasma torch in a flowing gas; heating the coating material in the plasma torch to a molten or semi-molten state using a nominal power below 25kW; and depositing the coating material with the plasma torch directly on the surfaces to be coated. The component may be made of a magnesium alloy containing at one or more of zinc, cerium and zirconium, or of an aluminum alloy containing one or more of magnesium, silicon, copper and chromium. The powder material may be made in majority of aluminum.

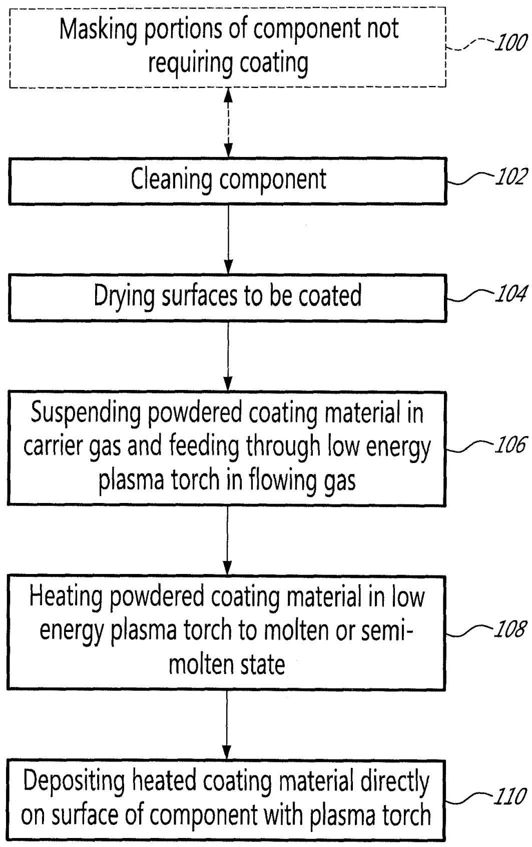

FIG. 3

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Description

TECHNICAL FIELD

[0001] The application relates generally to coating and, more particularly, to a method suited for coating by low energy plasma gas turbine engine components.

BACKGROUND OF THE ART

[0002] In a gas turbine engine, it is known to provide alloy components such as engine casings with an appropriate metal coating, for example for improved resistance to corrosion, wear, heat and/or abrasion. An intermediate bond coat is usually required between the alloy component and the metal coating to provide for adequate bond strength. The application of the bond coat however provides for additional costs and manufacturing steps in the production of the coated component.

SUMMARY

[0003] In one aspect, there is provided a method of coating an aluminum alloy or magnesium alloy component, the method comprising: cleaning and drying surfaces of the component to be coated; suspending a powdered coating material in a carrier gas and feeding the suspended powdered coating material through a plasma torch in a flowing gas; heating the coating material in the plasma torch to a molten or semi-molten state using a nominal power output below 25KW; and depositing the coating material with the plasma torch directly on the surfaces to be coated.

[0004] In another aspect, there is provided a method of coating an aluminum alloy or magnesium alloy component, the method comprising: cleaning and drying aluminum alloy or magnesium alloy surfaces of the component to be coated; suspending a coating material made in majority of aluminum in a carrier gas and feeding the suspended powdered coating material through a plasma torch in a flowing gas; heating the coating material in the plasma torch to a molten or semi-molten state; and depositing the coating material with the plasma torch directly on the surfaces to be coated.

[0005] In a further aspect, there is provided a method of coating a magnesium alloy component containing at least one material selected from the group consisting of zinc, cerium and zirconium, the method comprising: suspending an aluminum-based powdered coating material in a carrier gas and feeding the suspended powdered coating material through a plasma torch in a flowing gas; heating the coating material in the plasma torch to a molten or semi-molten state; and depositing the coating material with the plasma torch directly on clean and dry surfaces of the component to be coated, the plasma torch having a power output below 25KW.

DESCRIPTION OF THE DRAWINGS

[0006] Reference is now made to the accompanying figures in which:

Fig. 1 is a schematic cross-sectional view of a gas turbine engine;

Fig. 2 illustrates relative bond strength resistance values of aluminum coatings on a surface of a magnesium alloy component obtained by low and high energy plasma with and without an intermediate bond coat; and

Fig. 3 is a diagram of a method of coating a component in accordance with a particular embodiment.

DETAILED DESCRIPTION

[0007] Fig.1 illustrates a gas turbine engine 10 of a type preferably provided for use in subsonic flight, generally comprising in serial flow communication an air inlet 12 through which ambient air enters the engine, a compressor section 14 for pressurizing the air, a combustor 16 in which the compressed air is mixed with fuel and ignited for generating an annular stream of hot combustion gases, and a turbine section 18 for extracting energy from the combustion gases. The turbine section 18 includes a power turbine driving an output shaft 22 which in turn drives a propeller 24 through a reduction gearbox 26. Although the gas turbine engine 10 has been shown here as a turboprop engine, it is understood that in other embodiments the engine 10 may be a turbofan engine, a turboshaft engine, an APU, etc.

[0008] A number of components of the engine 10 require protection from corrosion, wear, heat and/or abrasion. In a particular embodiment, the component 28 being coated is an inlet case of the engine 10, which defines the engine inlet 12. Other components may also be coated as described herein, for example the front housing, gearbox, pump, rear case, front case, covers, etc.

[0009] One method of applying a coating is the use of plasma spray deposition, where a powdered coating material suspended in a suitable carrier gas is fed into a stream of flowing gas which is ionized and heated to extremely high temperatures by an electric arc. The coating particles are heated to plasticity and carried onto the component in the resulting high velocity plasma stream.

[0010] Alloy components, for example made of magnesium or aluminum alloy, were previously protected by a metal coating, for example an aluminum-based coating, applied through high energy plasma spray deposition (e.g. using a plasma gun with a power output of 40 KW), but an intermediate bond coat, for example made of a nickel alloy, was required between the component and the aluminum coating to obtain a desired bond strength. The inventor has found that by using a low energy plasma spray deposition method (e.g. using a plasma gun with a power output of 16 KW), the aluminum coating can be directly applied to the alloy component 28 without the use of the intermediate bond coat, while still achieving the desired bond strength.

[0011] In a particular embodiment, the component 28 is made of a magnesium alloy containing at least one material selected from the group consisting of zinc, cerium and zirconium. In a particular embodiment, the alloy has a composition by weight including, in addition to magnesium, from 3.5% to 5.0% of zinc (Zn), from 0.75% to 1.75% of total rare earths (principally a mixture of cerium, lanthanum, neodymium and praseodymium with a cerium of content of at least 45% of the total rare earths) and from 0.40% to 1.0% of zirconium (Zr).

[0012] In a particular embodiment, the magnesium alloy is AMS 4439 or similar, with a composition by weight including from 3.5% to 5.0% of zinc (Zn), from 0.75% to 1.75% of total rare earths (with a cerium of content of at least 45% of the total rare earths), from 0.40% to 1.0% of zirconium (Zr), up to 0.15% of manganese (Mn), up to 0.10% of copper (Cu), up to 0.01% of nickel (Ni) and up to 0.3% total of other elements (with up to 0.1 % per other element), the balance being magnesium (Mg).

[0013] In another embodiment, the component 28 is made of an aluminum alloy containing at least one material selected from the group consisting of magnesium, silicon, copper and chromium. In a particular embodiment, the aluminum alloy has composition by weight including, in addition to aluminum, from 0.8% to 1.2% of magnesium (Mg), from 0.4% to 0.8% of silicon (Si), from 0.15% to 0.40% of copper (Cu) and from 0.04% to 0.35% of chromium (Cr).

[0014] In a particular embodiment, the aluminum alloy is similar to AISI 6061, with a composition by weight including from 0.8% to 1.2% of magnesium (Mg), from 0.4% to 0.8% of silicon (Si), from 0.15% to 0.40% of copper (Cu), from 0.04% to 0.35% of chromium (Cr), up to 0.7% of iron (Fe), up to 0.25% of zinc (Zn), up to 0.15% of titanium (Ti) and up to 0.15% of manganese (Mn), the balance being aluminum (Al) and impurities.

[0015] The coating is provided in powder form and applied through low energy plasma spray deposition. In a particular embodiment, the coating powder is made in majority of aluminum. In a particular embodiment, the coating powder is made in majority of aluminum and includes, by weight, from 11% to 13% of silicon (Si).

[0016] In a particular embodiment, the coating powder has a composition by weight including from 11% to 13% of silicon (Si), up to 0.80% of iron (Fe), up to 0.30% of copper (Cu), up to 0.20% of zinc (Zn), up to 0.15% of manganese (Mn), up to 0.10% of magnesium (Mg) and up to 0.1% total of other elements (with up to 0.05% per other element), the balance being aluminum (Al).

[0017] Referring to Fig. 2, it has been found that the use of a low energy plasma deposition method to provide for a aluminum coating on a magnesium alloy component such as described above provides for similar bond strength values for both a coating applied directly to the component (Low energy, Al) and a coating applied over an intermediate nickel-based bond coat (Low energy, Al/Ni), which is also similar and in some cases slightly superior than the bond strength of a similar coating applied to a similar component through high energy plasma deposition over an intermediate nickel-based bond coat (High energy, Al/Ni). It can be also seen that the bond strength of the similar coating applied directly to the similar component, without the intermediate nickel-based bong coat (High energy, Al) is significantly lower, e.g. more than half the bond strength obtained through the low energy plasma deposition. The use of a low energy plasma spray method thus allows for the aluminum coating to have sufficiently good adherence to the surface of the magnesium alloy component that the intermediate bond coat can be omitted, which may help reduce the cost, time and complexity of the coating application.

[0018] Similar results have also been observed for the application of an aluminum-silicon coating as described above on an aluminum alloy casting component.

[0019] In a particular embodiment, the bond strength achieved through the low energy plasma deposition is at least 3000 Psi; in a particular embodiment, the bond strength achieved is at least 7000 Psi.

[0020] In a particular embodiment and in reference to Fig. 3, the component 28 is coated in accordance with the following.

[0021] Prior to the application of coating, the portions of the component 28 which must not be coated, if any, are suitably masked, as set forth in 100. The component 28 is also appropriately cleaned to be free from dirt, grit, oil, grease and other foreign materials, as set forth in 102. For example, the surfaces to be coated may be conditioned by blasting. In a particular embodiment, the blasting medium is aluminum oxide, zirconium oxide, or a mixture of these media; care is taken to avoid distortion or the embedding of abrasive particles due to excessive blast pressure. Loose abrasive particles are removed from the component before proceeding with the plasma spray coating.

[0022] The surfaces to be coated are dried, as set forth in 104. In a particular embodiment, drying is achieved by preheating the component, for example, through control of the dwell time of the plasma spray torch immediately prior to spraying.

[0023] As can be seen at 106, the blended powdered coating material is suspended in the carrier gas and fed into the stream of flowing gas which is ionized and heated by the electric arc, thus heating the coating material to a molten or semi-molten state, as set forth in 108. In a particular embodiment, the carrier gas and the flowing gas are argon, helium, a mixture of argon and helium, or a mixture of either of these gases with up to 20% hydrogen by volume.

[0024] In a particular embodiment, both the carrier gas and the primary flowing gas are argon, and hydrogen is provided as a secondary flowing gas, with the flow of primary gas being about 40 Umin, the flow of secondary gas being about 1 L/min, and the flow of carrier gas being about 4 Umin, with the powder feed being from 8 g/min to 12 g/min. In a particular embodiment, the flow of primary gas within a range of 40 Umin ± 10%, the flow of secondary gas is within a range of 1 L/min ± 10%, and/or the flow of carrier gas is within a range of 4 Umin ± 10%.

[0025] The heated coating particles are deposited directly on the surface of the component through the high velocity plasma stream, as set forth in 110. In a particular embodiment, the plasticized coating particles are accelerated to a speed in the range of 200 to 300 m/s.

[0026] In a particular embodiment, the low energy plasma spray deposition maintains the temperature of the component during spraying below 400°F (204°C).

[0027] In a particular embodiment, the plasma spray deposition is performed a distance of 1 inch (25.4mm) from the surface of the component 28 to be coated.

[0028] In a particular embodiment, "low energy plasma deposition" is defined as being performed using a plasma torch with a nominal power of below 25kW, preferably at most 16kW. In a particular embodiment, the low energy plasma deposition is performed using a SM-F210 plasma gun manufactured by Sulzer Metco. However, it is understood that any other suitable low energy plasma torch may be used.

[0029] To form the coating, the head of the plasma torch may pass over the surface of the component 28. The number of passes required is a function of the thickness of the coating to be applied. The torch may be held stationary to form a thick deposit over the area to be coated. It is however desirable to limit the thickness per pass in order to avoid a quick build up of residual stresses and unwanted debonding between deposited layers.

[0030] The component 28 is thus coated by applying the coating directly to its surface, i.e. without the use of an intermediate bond coat.

[0031] The application method may also be used for the repair of the alloy components using an aluminum-containing repair material. When repairing an alloy component of, for example, a gas turbine engine, corrosion pits and/or damaged areas are mechanically removed, for example through grinding, machining or other applicable techniques. The resulting surface may optionally be grit blasted prior to depositing the aluminum-containing repair material using the above described method. In at least an embodiment, the metal containing repair material comprises a material which has a composition that includes more that 50% by weight of aluminum.

Example 1

[0032] Parameters of a high energy and low energy plasma projections according to a particular embodiment are set forth below:

	Primary gas flow (Argon) (SCFH)	Secondary gas flow (H_2) (SCFH)	Amp. (A)	Nominal Power (kW)	Spray distance (inch)	Powder feed rate (g/min)	Max. Coating Temp. (°C)
Low energy	84,75	2,12	320	10.4	1	3	120
High energy	96	20	500	73	5	75,6	N/A

Example 2

[0033] A magnesium alloy component made of AMS 4439 was coated by low energy plasma using a powder having a composition by weight including from 11% to 13% of silicon, up to 0.80% of iron, up to 0.30% of copper, up to 0.20% of zinc, up to 0.15% of manganese, up to 0.10% of magnesium and up to 0.1 % total of other elements (with up to 0.05%

per other element), the balance being aluminum. The particle size distribution of the coating powder was in conformity with (where + indicates retained on sieve and-indicates passing sieve):

	% by weight	
ASTM Sieve	minimum	maximum
+140	-	1
+170	-	7
-325	-	10
+325	90	-

[0034] The coating was performed using a SM-F210 Internal Plasma spray gun by Sulzer Metco as the low energy plasma torch, having a power output of 16kW.

[0035] The coating was sprayed using the following parameters:

Primary gas flow: Argon, 40 Umin

Secondary gas flow: Hydrogen, 1 Umin

Carrier gas flow: Argon, 4 Umin

Power: 300 Amps

Spray distance: 1 inch

Power feed rate: 8 to 12 g/min

[0036] The surface of the magnesium alloy component was subjected to a regular grit blast prior to the coating.

[0037] The bond strength of the coated magnesium alloy component thus obtained was 7000 Psi, the coating hardness was 79.6 HV, and the average coating thickness was 0.016 inch.

[0038] A corrosion immersion test was performed by immersing samples in a solution of 3.5% NaCl in deionized water. A weight loss of 19% was observed after an immersion of 48 hours, with an average thinning rate of 1% per hour. A salt spray test was also performed using a spray solution of 5% NaCl in deionized water. A weight loss of 3% was observed after 46 hours in the spray.

[0039] As such, despite the absence of the bond coat, the corrosion resistance was shown to be within acceptable values.

[0040] The above description is meant to be exemplary only, and one skilled in the art will recognize that changes may be made to the embodiments described without departing from the scope of the invention disclosed. Modifications which fall within the scope of the present invention will be apparent to those skilled in the art, in light of a review of this disclosure, and such modifications are intended to fall within the appended claims.

Claims

1. A method of coating an aluminum alloy or magnesium alloy component, the method comprising:

cleaning and drying surfaces of the component to be coated;
suspending a powdered coating material in a carrier gas and feeding the suspended powdered coating material through a plasma torch in a flowing gas;
heating the coating material in the plasma torch to a molten or semi-molten state using a nominal power output below 25kW; and
depositing the coating material with the plasma torch directly on the surfaces to be coated.

2. The method as defined in claim 1, depositing the coating material with the plasma torch is performed while maintaining a temperature of the surfaces to be coated below 400°C.

3. The method as defined in claim 1 or 2, wherein the plasma torch has a power output of at most 16KW.

4. A method of coating an aluminum alloy or magnesium alloy component, the method comprising:

cleaning and drying aluminum alloy or magnesium alloy surfaces of the component to be coated;
suspending a coating material made in majority of aluminum in a carrier gas and feeding the suspended powdered coating material through a plasma torch in a flowing gas;
heating the coating material in the plasma torch to a molten or semi-molten state; and
depositing the coating material with the plasma torch directly on the surfaces to be coated.

5. The method as defined in claim 4, wherein the plasma torch has a power output below 25KW.

6. The method as defined in any preceding claim, wherein depositing the coating material with the plasma torch directly on the surfaces to be coated includes depositing the coating material directly on the surfaces made of a magnesium alloy containing at least one material selected from the group consisting of zinc, cerium and zirconium.

7. The method as defined in claim 6, wherein the magnesium alloy has a composition by weight including from 3.5% to 5.0% of zinc, from 0.75% to 1.75% of total rare earths with a cerium of content of at least 45% of the total rare earths, and from 0.40% to 1.0% of zirconium.

8. The method as defined in any of claims 1 to 5, wherein depositing the coating material with the plasma torch directly on the surfaces to be coated includes depositing the coating material directly on the surfaces made of an aluminum alloy containing at least one material selected from the group consisting of magnesium, silicon, copper and chromium.

9. The method as defined in claim 8, wherein the aluminum alloy has a composition by weight including from 0.8% to 1.2% of magnesium, from 0.4% to 0.8% of silicon, from 0.15% to 0.40% of copper, and from 0.04% to 0.35% of chromium.

10. The method as defined in any preceding claim, wherein suspending the blended powdered coating material includes suspending a powder material made in majority of aluminum.

11. The method as defined in claim 10, wherein the powder material includes, by weight, from 11 % to 13% of silicon.

12. The method as defined in any claims 1 to 9, wherein suspending the blended powder coating material includes suspending an aluminum based material.

13. The method as defined in any preceding claim, wherein depositing the coating material includes accelerating the molten or semi-molten coating material to a speed of from 200 to 300 m/s.

14. The method as defined in any preceding claim, wherein depositing the coating material includes projecting the coating material at a rate of from 8 to 12 g/min.

15. The method as defined in any preceding claim, wherein suspending the powdered coating material in a carrier gas includes suspending the powdered coating material in argon, and feeding the suspended powdered coating material through a plasma torch in a flowing gas includes feeding the suspended powered coating material in a primary gas flow of argon with a secondary gas flow of hydrogen smaller than the primary gas flow.

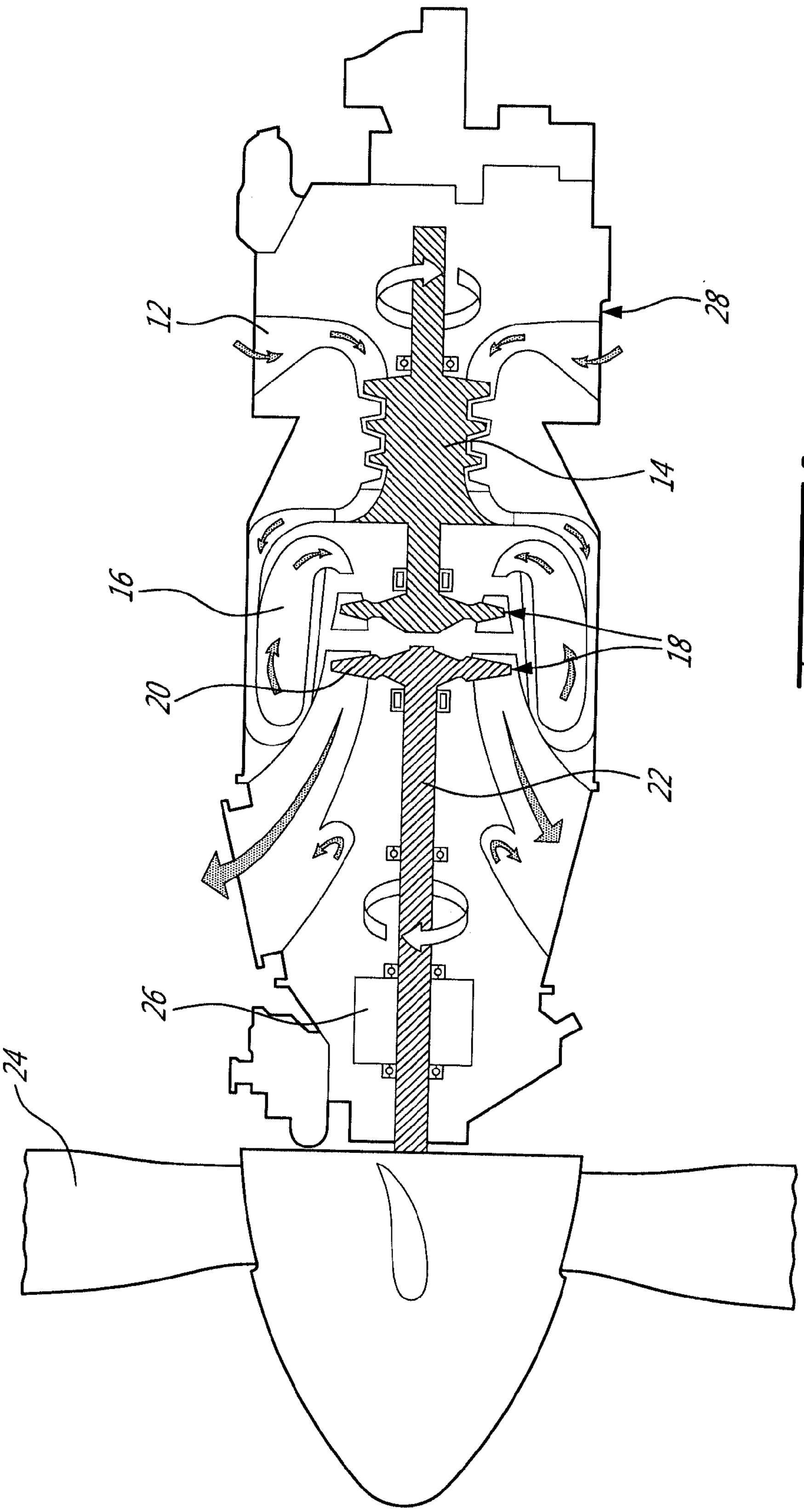

Fig-1

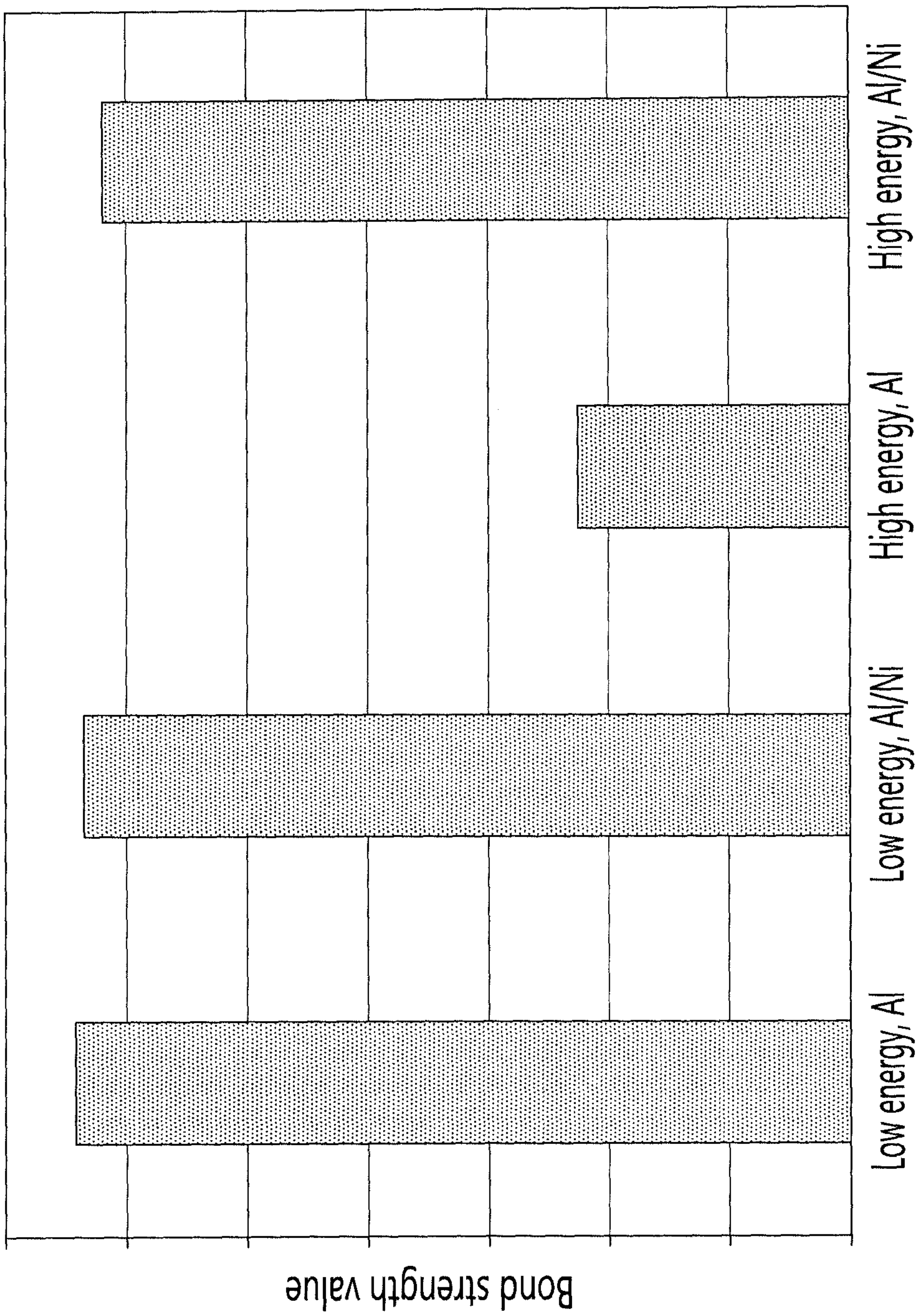
Bond strength value
Low energy, Al
Low energy, Al/Ni
High energy, Al
High energy, Al/Ni

FIG - 2

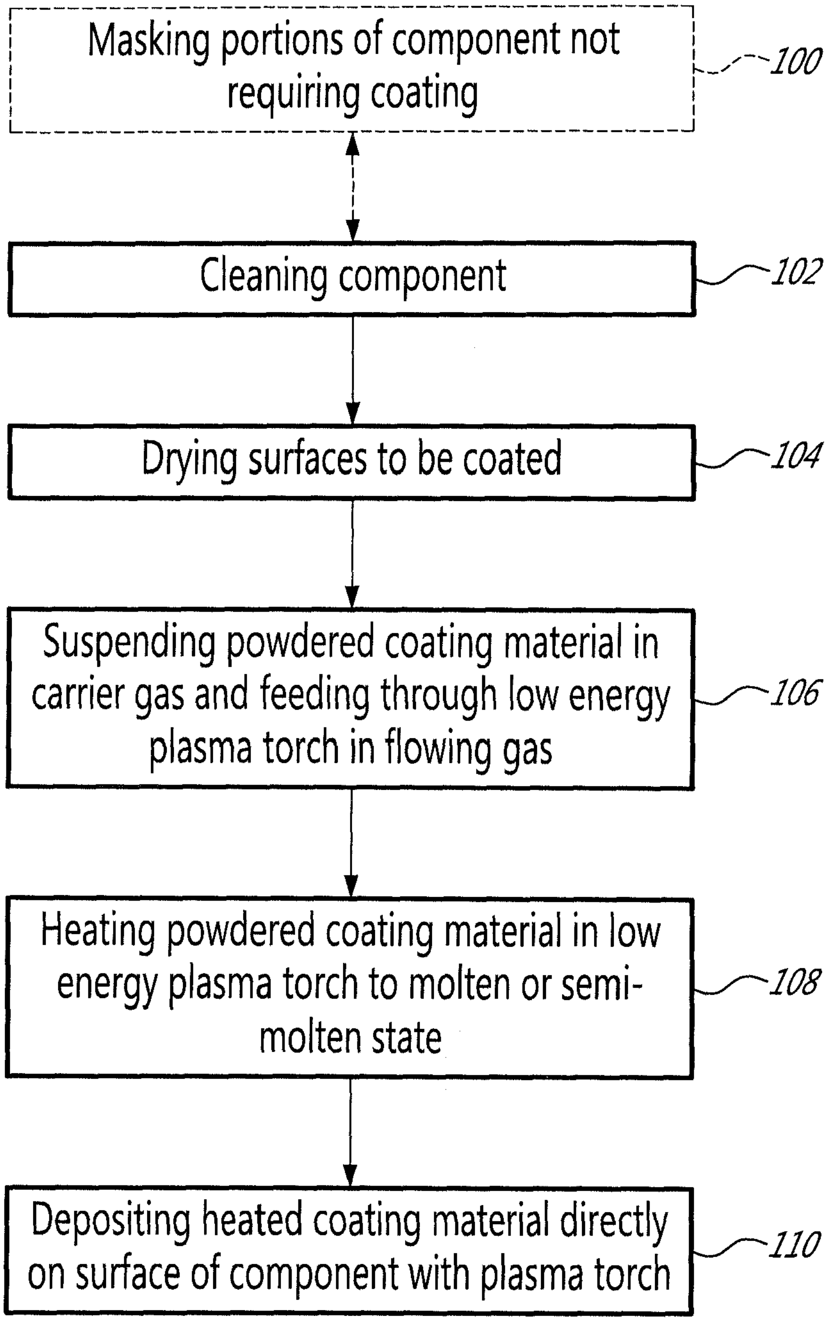
Masking portions of component not requiring coating
100
Cleaning component
102
Drying surfaces to be coated
104
Suspending powdered coating material in carrier gas and feeding through low energy plasma torch in flowing gas
106
Heating powdered coating material in low energy plasma torch to molten or semi-molten state
108
Depositing heated coating material directly on surface of component with plasma torch
110

FIG. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 14 15 7078

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	BAO M ET AL: "The Tribological Behavior of Plasma-Sprayed Al-Si Composite Coatings Reinforced with Nanodiamond", JOM, vol. 64, no. 6, 3 June 2012 (2012-06-03), pages 702-708, XP035071455, The Minerals, Metals & Materials Society; Springer, Boston, MA [US] ISSN: 1543-1851, DOI: 10.1007/S11837-012-0339-8 * page 703; table 1 * -----	1-5,8-14	INV. C23C4/10 C23C4/12 F01D5/00
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A	US 6 221 504 B1 (PFEFFINGER HARALD [DE] ET AL) 24 April 2001 (2001-04-24) * column 1, lines 12-16 * * column 3, lines 12-27; example 3 * ----- -/--	1-15	C23C F01D

1

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	27 May 2014	Hoyer, Wolfgang

CATEGORY OF CITED DOCUMENTS

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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 (IPC)
A	QIAN M ET AL: "Corrosion performance of laser-remelted Al-Si coating on magnesium alloy AZ91D", CORROSION SCIENCE, vol. 52, no. 10, 11 July 2010 (2010-07-11), pages 3554-3560, XP027206825, Elsevier B.V., Amsterdam [NL] ISSN: 0010-938X, DOI: 10.1016/j.corsci.2010.07.010 [retrieved on 2010-07-11] * page 3555, left-hand column * -----	1-15	
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TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

1

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