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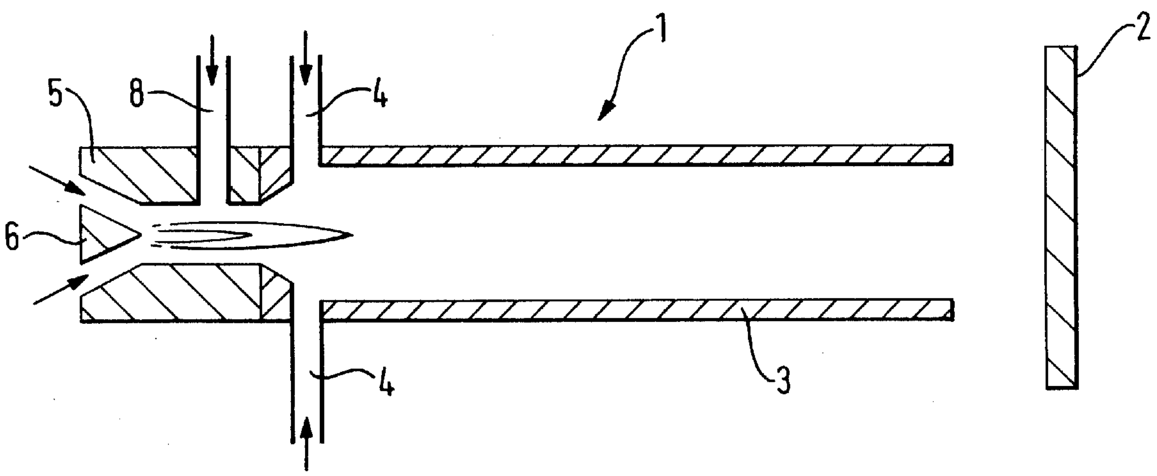
(54) Improved plasma spraying

(57) An apparatus 1 for the plasma spraying of a substrate 2 comprises a reaction chamber 3 at one end of which is located a plasma torch. A plasma forming gas is delivered under pressure to the torch such that a plasma jet is produced which extends along the length of the reaction chamber 3. An inlet port 8 is provided in the torch for the passage therethrough of a powder material and inlet ports 4 are provided in the reaction chamber 3 for injecting a reactive gas such as methane into the plasma jet.



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Description

The present invention relates to the plasma spraying of a substrate with a coating or coatings which exhibit enhanced properties of hardness and/or wear resistance. Conventional plasma spraying involves injecting powder particles typically in the range of 20 - 150 µm into a plasma arc generated by a plasma gun or torch. The powder particles become molten or partially molten and are accelerated towards the substrate to be coated. Impact with the substrate causes the powder particles to solidify rapidly and coalesce to form a coating.

US Patent No 5217747, for example, discloses an apparatus for the plasma spraying of a substrate which includes a reaction chamber at one end of which is located a d.c. plasma torch. Means is provided for the supply of a plasma forming gas under pressure to the torch such that a plasma jet is produced which extends along the length of the reaction chamber. Aluminium powder is introduced into the plasma jet adjacent the plasma torch.

However, interactions between the molten or partially molten powder particles and the atmosphere often causes undesirable defects such as oxide stringers in the final coating. Considerable work has been done in an effort to reduce these interactions which have lead to the development of processes such as "Low Pressure Plasma Spraying" and "Vacuum Plasma Spraying".

It is an aim of the present invention to provide an apparatus for the reactive plasma spraying of a substrate which overcomes or minimizes the aforesaid disadvantages of conventional plasma spraying by reducing the oxide content of a sprayed material during spraying in the presence of air.

According to one aspect of the present invention, an apparatus for the plasma spraying of a substrate comprises a reaction chamber at or adjacent one end of which is located an anode electrode and space therefrom a cathode electrode, means for applying a direct current between the electrodes, means for supplying a plasma forming gas under pressure between the electrodes such that, in use a plasma jet is produced which extends along the length of the reaction chamber from the said one end, means for supplying a powder material into the plasma jet and further means for injecting a reactive gas into the plasma jet.

Preferably the reactive gas is a hydrocarbon, for example, methane.

In one embodiment the powder material is a mixture of 80% nickel and 20% chromium by weight. Alternatively, the powder material is an alloy of M, Cr, Al, Y where M is a metal selected from nickel, cobalt, an alloy of nickel/cobalt or iron.

According to a further aspect of the present invention of a method of reducing the oxygen content of coatings applied to a substrate by reactive plasma spraying in air comprises the steps of

a) creating a plasma jet and accelerating the plasma jet towards the substrate;
b) applying a powder material into the plasma jet; and
c) injecting a reactive gas into the plasma jet

An embodiment of the invention will now be described, by way of example, reference being made to the Figure of the accompanying diagrammatic sketch which is a cross section through an apparatus according to the present invention.

As shown, an apparatus 1 for use in the coating of a substrate 2 includes a reaction chamber 3 having one or more through ports 4 arranged at or adjacent the left hand end (as shown) of the reaction chamber 3 for the passage therethrough of a reactive gas.

The reaction chamber 3 is attached to a plasma spray gun or torch at its left hand end (as shown) which plasma spray gun includes an anode electrode 5 and a cathode electrode 6. The anode electrode 5 is formed as a nozzle and a direct current power source (not shown) connects the electrodes 5, 6 in a manner known per se. An inlet port 8 is provided in the gun for the passage therethrough of powder material again as known per se.

In a particular example a reaction chamber 3 was attached to a Miller Thermal Inc. model SG-100 plasma gun and the following table illustrates the spraying parameters.

Table I

Spraying Parameters	
Power	40 kW
Arc Current	800 Amps
Arc Gas / Pressure	Ar / 50 Psi
Aux Gas / Pressure	He / 100 Psi
Powder Hopper Rotation	4 R.P.M.
Powder gas / Pressure	Ar / 40 Psi

Table I (continued)

Spraying Parameters	
Powder Injection	Internal
Powder (Plasmalloy)	Al 1015

Two coatings were deposited on the substrate 2 with identical spraying parameters other than one coating had methane injected into the plasma jet through the ports 4 at a flow rate of 24 litres per minute (example A) and the other (example B) did not. Sprayed samples were cut into cross-section, mounted, ground and polished. The coatings mechanical properties were measured using a Vickers Microhardness machine. A summary of the parameters and hardness results can be seen in Table II.

Table II

Effect of reactive gas		
Coating	Reactive gas/Flow rate	Hardness /Hv
A	CH4/24 L min^{-1}	451.8 ± 33
B	None	212.6 ± 12

The hardness results clearly show that injecting methane had a profound effect on coating properties. This increase in hardness may be due to the formation of ultra fine carbides and / or interstitial solid solution strengthening.

The above results indicate that by modifying a conventional DC Plasma torch by attaching to it a reaction chamber with ports 4 for the injection of a reactive gas, can yield significant increases in properties for 80/20 nickel chrome alloys. The reaction chamber 3 increases the residence time for chemical reactions to occur within the plasma. It is evident that the addition of the reaction gas eg methane is leading to coatings which are significantly harder and of improved wear resistance.

It has also been found that addition of the reactive gas e.g. methane is having the effect of reducing the oxide content of the resulting coatings. M Cr Al Y are alloys of chromium, aluminium and yttrium together with another metal, for example, nickel, cobalt, an alloy of these or iron. When spraying alloys of this class for certain applications, in the past it was essential to use an expensive vacuum spraying technique in order to reduce the oxygen content to a minimum. It has been found that this class of alloys can be sprayed with excellent results using the apparatus described hereinbefore. It is believed that the reactive gas, that is methane reduces the possibility of oxide formation and may promote the formation of carbides.

To obtain similar results previously it was necessary to plasma spray in inert atmospheres which is very expensive.

It has been found advantageous to use at least three ports 4 slightly offset from the axis of the reaction chamber 3 to give the reactive gas a swirling motion as it passes along the length of the chamber 3.

In one embodiment the reaction chamber is a consumable, made essentially of graphite. However, despite the presence of carbon in the walls of the reaction chamber 3 it has been found necessary still to inject a reaction gas through the ports 4.

Tables III and IV illustrate the manner in which the oxide content of air sprayed plasma coatings is reduced by the injection of a reaction gas into the reaction chamber 3.

Table III

REACTIVE PLASMA Ni - Cr				
	No Reactive Gas		With Reactive Gas	
	B	A	B	A
Oxygen (Wt %)	1.4	1.5	0.14	0.16
Hardness (Vickers)	212	206	452	232
A = 10cm Reactor B = 15cm Reactor				

Table IV

REACTIVE PLAMSA MCr AlY		
	No Reactive Gas	With Reactive Gas
Oxygen (Wt %)	1.5 (A)	0.12
	3.6 (B)	0.35
Powder Sizes (A) - 75 + 45 µm (B) - 37 + 5 µm		

Claims

1. An apparatus 1 for the plasma spraying of a substrate 2 comprising a reaction chamber 3 at one end of which is located an anode electrode 5 and space therefrom a cathode electrode 6, means for applying a direct current between the electrodes, means for supplying a plasma forming gas under pressure between the electrodes such that, in use a plasma jet is produced which extends along the length of the reaction chamber 3 from said one end and means 8 for supplying powder material into the plasma jet characterised in that further means is provided for injecting a reactive gas into the plasma jet.

2. An apparatus as claimed in claim 1, in which the reactive gas is a hydrocarbon gas

3. An apparatus as claimed in claim 2, in which the hydrocarbon gas is methane

4. An apparatus as claimed in any one of claims 1 to 3 in which the powder material is a mixture of 80% nickel and 20% chromium by weight

5. An apparatus as claimed in any one of claims 1 to 3 in which the powder material is an alloy M, Cr, Al, Y where M is a metal selected from nickel, cobalt, an alloy of nickel/cobalt or iron.

6. An apparatus as claimed in any one of claims 1 to 5, in which the reaction chamber 3 is made from a consumable material.

7. An apparatus as claimed in claim 6, in which the consumable material is graphite.

8. An apparatus as claimed in any one of claims 1 to 7, in which said further means for injecting a reactive gas into the plasma jet comprises at least three ports 4 offset from the axis of the reaction chamber 3 to impart to the reactive gas a swirling motion.

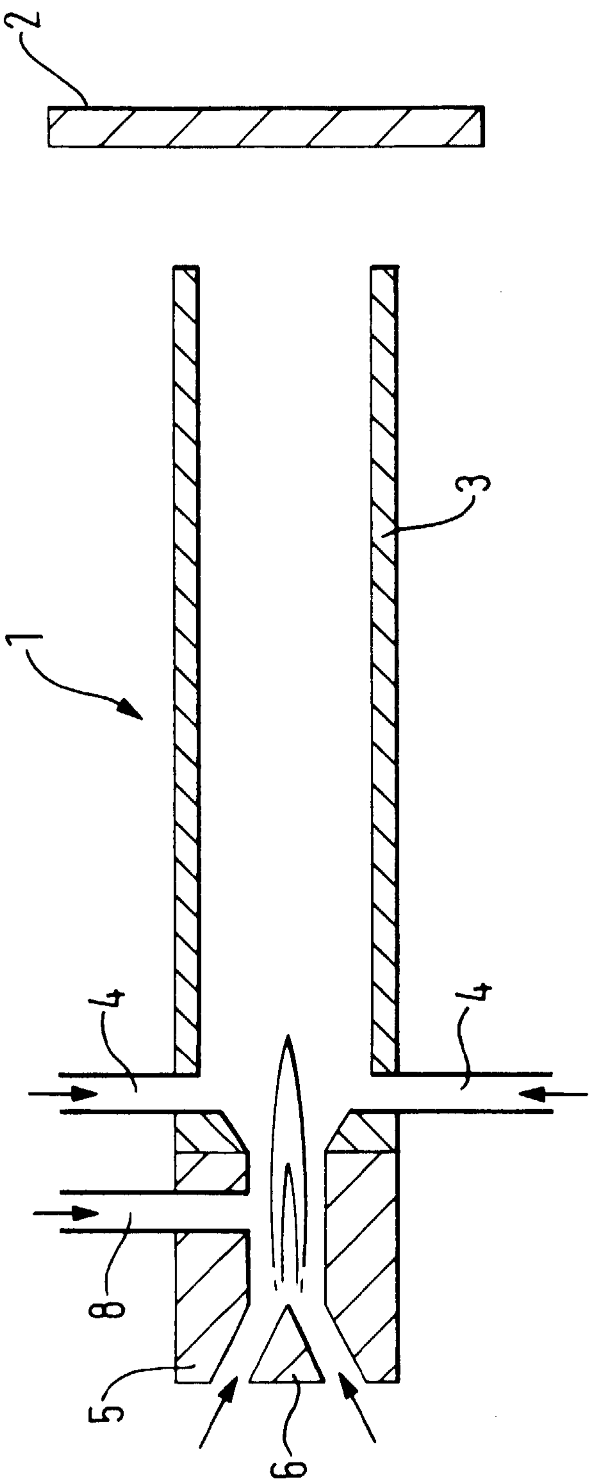
9. A method of reducing the oxygen content of coatings applied to a substrate by reactive plasma spraying in air comprising the steps of

   a) creating a plasma jet and accelerating the plasma jet towards the substrate;
   b) applying a powder material into the plasma jet; and
   c) injecting a reactive gas into the plasma jet

10. A method as claimed in claim 9, in which the reactive gas is a hydrocarbon gas

11. A method as claimed in claim 10, in which the reactive hydrocarbon gas is methane.

12. In combination, a plasma torch to which is attached a reaction chamber 3 formed with at least one port 4 for the passage thereinto of a reactive gas, the combination being such that in use a plasma jet generated by the plasma torch accelerates along the length of the reaction chamber 3 and into which jet is injected the reaction gas.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