

1 Improvements Relating to the Production of Coatings

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3 This invention relates to apparatus and processes
4 for the production by electrolytic or electroless
5 deposition of composite coatings which consist of a
6 metal matrix containing particles in which processes
7 the particles are co-deposited with the metal from a
8 solution in which the particles are insoluble. The
9 invention is primarily concerned with the deposition of
10 ceramic, cermet or metal particles in coatings in which
11 it is essential to accurately control the composition
12 of the composite produced. Such coatings may be used
13 for various purposes including wear and abrasion
14 resistance, corrosion and oxidation resistance and
15 improvements in coefficient of friction (lubricity) and
16 anti-fretting and anti-galling properties. In
17 certain cases the coatings themselves may constitute
18 the final product so that the process is one of
19 electroforming.

20 The general process comprises electroplating in a
21 bath containing insoluble particles dispersed in the
22 electrolyte, the particles being codeposited with the
23 metal deposited from the electrolyte. A similar
24 process may be used for electroless deposition but for
25 the most part the description will refer only to
26 electrolytic deposition.

27 There is described in GB 2 182 055A a process for
28 the electrodeposition of a composite coating comprising
29 a metal matrix containing particles, the particles
30 being codeposited with the metal from a solution in
31 which the particles are insoluble and in which process
32 gas is admitted to the solution at a location to
33 produce circulation in the solution generally upwards

1 in one zone and generally downwards in a second zone
2 and the workpiece is located in the second zone. The
3 two zones can, if necessary be separated by a partition
4 or weir especially if particularly large particles
5 (greater than 50 μm diameter) are to be codeposited
6 since the presence of the partition produces quiescent
7 conditions necessary for the unhindered settling of
8 these particles onto the workpiece where they become
9 embedded in the metal which is being simultaneously
10 plated out.

11 One particular class of composite coatings which
12 may be produced by the apparatus is that comprising a
13 matrix of Ni, Co or NiCo with particles of CrAlV.

14 The apparatus described in GB 2182055A produces
15 the settling condition essential to the production of
16 such coating. It has now been appreciated that to
17 produce coatings of uniform composition on components
18 of complex geometry like the turbine blades of
19 aeroengines the codeposition of powder on all surfaces
20 must be maintained at or close to a maximum or
21 saturated level by which is meant that during
22 co-deposition the particles should be present on the
23 surface in quantities and geometrical arrangement which
24 are as close as possible to maximum or natural packing
25 density for the particles concerned; otherwise local
26 changes in current density will give rise to variations
27 in composition. Problems also arise with turbine
28 blades because of their abrupt changes of shape at the
29 leading and trailing edges.

30 According to the present invention, a process for
31 the production by electrolytic or electroless
32 deposition on a workpiece of a composite coating
33 comprising a metal matrix containing the particles, the

1 particles being codeposited with the metal from a
2 solution in which the particles are insoluble,
3 comprises inducing circulation in the solution
4 generally upwards in one zone and generally downwards
5 in a second zone, locating the workpiece in the second
6 zone, and rotating the workpiece about an axis having a
7 horizontal component, the rotational cycle including
8 periods of higher angular velocity and periods of lower
9 angular velocity.

10 For most applications, probably the most
11 satisfactory arrangement of rotation will be
12 alternately stop and go and the following description
13 will mainly be directed to such arrangements but in
14 some cases, for example where the particles are very
15 small (e.g. between one and 10 μm), it may not be
16 necessary to come to a dead stop between each faster
17 period. In certain cases, more complex cycles may be
18 most appropriate so there may be more than two
19 repeating speeds of rotation; likewise the transition
20 from one speed to the other or another may take various
21 forms; indeed there may be no period of constant
22 angular velocity, the speed changing continuously but
23 at varying rates throughout a complete cycle.

24 The effect of stopping (or slowing down) the
25 rotation is that particles are able to settle and
26 remain on the upwardly facing surface of the workpiece
27 to be trapped by the matrix metal being deposited so
28 that a high volume of particles relative to matrix can
29 be achieved. This is particularly important where the
30 workpiece is irregular, particularly where it has quite
31 abrupt edges or transitions such as the leading and
32 trailing edges of aerofoil sections.

33 The pattern of rotation may be adapted to the

1 workpiece being coated so that particular bands
2 (extending parallel with the axis of rotation) of the
3 workpiece surface face upwardly longer than others but
4 for most applications this is unnecessary provided that
5 all the bands have a sufficient dwell time facing
6 upwards.

7 The angular movement of the workpiece in the
8 faster periods (and in the slower periods if rotation
9 is not then completely stopped) may vary considerably.
10 For example, a stationary period may be followed by a
11 rapid rotation through only a few degrees before the
12 workpiece becomes stationary again, the successive
13 upwardly facing zones thus overlapping one another.
14 However, it is preferred for the workpiece to rotate
15 through a larger angle, possibly more than 360° and
16 possibly several complete revolutions between each
17 stationary period. Provided that the number of stop
18 and start periods in a complete plating operation is
19 large, a regular coating will be achieved, although it
20 is desirable that the arrangement is such that the
21 cycle is not repeated identically for each revolution
22 which could produce an uneven deposit around the axis
23 of rotation. Thus, in a possible example, the
24 workpiece is rotated at between one third and one half
25 revolutions per minute with each stop period being of
26 approximately ten seconds and each go period being of
27 approximately three seconds duration. This is suitable
28 for small particles in the 1 to 10 μm range when
29 plating at 10 mA/cm^2 . However much larger stationary
30 periods may be desirable for larger particles of or
31 greater than 100 μm .

32 Where, the workpiece is of irregular or complex
33 shape adequate inclusions of particles may not be

1 achieved on certain areas, even by use of the above
2 described techniques. For example, the workpiece may
3 have two surfaces which, when considered in a section
4 containing the longitudinal axis are at right angles to
5 one another or form a re-entrant. Therefore, particles
6 may run down one of the surfaces even when settling
7 satisfactorily on the other.

8 In one possible way of carrying out the process of
9 the invention the workpiece is also rotated about a
10 second axis which is non-parallel with the first. By
11 rotating the workpiece about a second axis, it can be
12 arranged that all surfaces to be coated face
13 sufficiently close to vertically upwards for a
14 sufficient proportion of the total plating time for
15 them all to be satisfactorily coated.

16 The invention may be applied to the apparatus and
17 methods described with reference to drawings in GB 2
18 182 055A and may be used, for example, to produce
19 coatings comprising a matrix of Ni, Co or NiCo with
20 particles of CrAlV. More detailed information
21 concerning such coatings may be obtained from
22 GB 2 167 466B.

23 The invention may be performed in various ways but
24 one form of apparatus and a method of coating using the
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1 apparatus will now be described by way of example with
2 reference to the accompanying diagrammatic drawings, in
3 which:

4 Figure 1 is a perspective view of the apparatus;

5 Figure 2 is a side elevation of the apparatus;

6 Figure 3 is a front elevation of the apparatus;

7 and

8 Figure 4 is a perspective view of the jig on which
9 the articles to be plated are suspended.

10 The apparatus shown in the drawings, comprises a
11 vessel or container 1 having a parallelepiped shaped
12 upper portion 2 and a downwardly tapering lower portion
13 3 in the form of an inverted pyramid which is skewed so
14 that one side face 4 forms a continuation of one side
15 face 5 of the upper portion.

16 The vessel 1 contains a partition 6 which lies in
17 a vertical plane parallel to the side faces 4 and 5 of
18 the vessel and makes contact at its side edges 7 and 8
19 with the adjacent vertical and sloping faces of the
20 vessel. The partition thus divides the vessel into a
21 larger working zone 9 and a smaller return zone 11. At
22 its bottom, the partition 6 terminates at a horizontal
23 edge 12 above the bottom of the vessel to afford an
24 interconnection 13 between the working zone 9 and the
25 return zone 11. At its top, the partition 6 terminates
26 at a horizontal edge 14 below the top edges of the
27 vessel 1.

28 At the bottom of the return zone 11 there is an
29 air inlet 15 which is connected to an air pump (not
30 shown). Mounted in the working zone 9 is a jig 21 to
31 which the workpiece to be coated are mounted, the jig
32 21 being arranged to move the workpieces within the
33 vessel in a manner to be described in greater detail

1 below.

2 When the apparatus is to be used for electrolytic
3 plating, conductors are provided to apply a voltage to
4 the workpiece mounted on the jig 21 relative to an
5 anode which is suspended in the working zone.

6 To use the apparatus, to codeposit a coating on
7 the workpieces, the workpieces are mounted on the jig
8 21 which is positioned in the vessel as shown. Before
9 or after the positioning of the jig, the vessel is
10 filled to a level 17 above the top edge 14 of the
11 partition 6 with a plating solution containing
12 particles to be co-deposited. Air is admitted to the
13 inlet 15 and this rises up the return zone 11, raising
14 solution and entrained particles. At the top of the
15 return zone, the air escapes and the solution and
16 particles flow over the broad crested weir formed by
17 the top edge 14 of the partition and flow down past the
18 workpieces on the jig 21. At the bottom of the working
19 zone 9, the particles tend to settle and slide down the
20 inclined sides of the vessel towards the
21 interconnection 13 where they are again entrained in
22 the solution and carried round again.

23 As the downwardly travelling particles in the
24 working zone 9 encounter the workpiece, they tend to
25 settle on the workpiece where they become embedded in
26 the metal which is being simultaneously plated out.

27 The workpieces to be coated are mounted on a jig
28 21 shown in Figure 4 which is suspended in the vessel
29 1. The jig is shown in simplified form in Figures 2
30 and 3 but omitted from Figure 1 for reasons of clarity.
31 The jig 21 comprises a deck 22 which fits over the top
32 of the vessel 1, a depending pillar 23 towards one end
33 and a pair of depending guides 24 at the other end.

1 The guides 24 have facing guideways in which slides a
2 cross-head 25 carrying a vertical rack 26 which passes
3 upwards through a hole 27 in the deck 22 and meshes
4 with a pinion 28 driven by a reversible electric motor
5 29. The deck 22 supports a second electric motor 31
6 which drives a vertical shaft 32 carrying a bevel
7 pinion 33 which engages a crown-wheel 34 fixed to one
8 end of a spindle 35 mounted in the pillar 23. The
9 other end of the spindle 35 is connected by a universal
10 joint 36 to one end of a shaft 37 the other end of
11 which is carried by a spherical bearing 38 in the
12 cross-head 25.

13 The shaft 37 carries a plurality of spurs which
14 are rigidly attached thereto, only one spur 39 being
15 shown in Figure 4. The spur 39 extends in a plane
16 containing the axis of the shaft 37 with the
17 longitudinal axis of the spur making an angle α with
18 the axis of the shaft 37. Mounted on the spur 39 and
19 spaced therealong are three gas turbine blades 42 to be
20 coated, with the longitudinal axes of the blades
21 extending in the said plane and perpendicular to the
22 longitudinal axis of the spur 39 so that the
23 longitudinal axes of the blades make angles of $(90-\alpha)^{\circ}$
24 to the axis of the shaft 37.

25 An electronic motor controller 43 is mounted on
26 the deck 22 and is connected by lines 44 and 45 to the
27 motors 29 and 31. The controller 43 is designed to
28 drive the motor 29 in one direction only but with a
29 stop so as to rotate the shaft 37 about a nominally
30 horizontal axis (the x-axis). The controller 43 is
31 designed to drive the motor 31 alternately in opposite
32 directions to reciprocate the cross-head 25 and so
33 superimpose on the rotation about the x-axis an

1 oscillatory rotation about a rotating axis in the
2 universal joint 36 (the y-axis).

3 The angle α and the parameters of the cycles
4 executed by the motors 29 and 31 are selected to suit
5 the workpiece being coated so as to ensure that all
6 surfaces to be coated spend sufficient time facing
7 generally upwardly to receive an adequate loading of
8 descending particles to be incorporated in the plated
9 metal as it is deposited.

10 One particular class of composite coatings which
11 may be produced by the apparatus described is that
12 comprising a matrix of Ni, Co or NiCo with particles of
13 CrAlY. It has been found that good quality coatings
14 containing up to 30% by weight of particles can be
15 produced using only 1 gram per litre of particles in
16 the solution.

17 One particular example of a coating and the method
18 of production thereof will now be described by way of
19 example.

20 EXAMPLE

21 The coating is to be produced on a gas turbine
22 blade 42 having an aerofoil section 43 with a root
23 portion 44 at one end and a shroud portion 45 at the
24 other end, the platforms of the root and shroud both
25 extending at angles of approximately 70° to the axis of
26 the aerofoil portion and the root portion and the
27 shroud portion having end faces which extend at
28 respectively 30° and 40° to the circumference of the
29 ring of which the blade forms part. For blades of this
30 geometry the angle α is 70° .

31 It is intended to produce on the aerofoil and
32 platform portions of the blade a coating containing
33 18.32 weight percent Cr, 8.25 weight percent Al, 0.457

1 weight percent Y and the remainder cobalt. To produce
2 such a coating the bath is filled with a cobalt plating
3 solution comprising 400 grams per litre of $\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$,
4 15 grams per litre of NaCl and 20 grams per litre of
5 boric acid H_3BO_3 . The bath is maintained at a pH of
6 4.5 and a temperature of 45°C . The bath is loaded with
7 powder to a concentration of 70 grams per litre, the
8 powder having a size distribution of 5 to 15
9 micrometres and being composed of 67.8 weight percent
10 chromium, 30.1 weight percent aluminium and 1.7 weight
11 percent yttrium.

12 Prior to coating the parts of the root and shroud
13 portions which are not be plated are given a wax mask
14 and the remaining surfaces are given the conventional
15 preparation treatments appropriate to cobalt plating.

16 The blade is fixed to the jig with its axis (see
17 Figure 4) at 20° to the x axis of the jig which is
18 horizontal (see Figure 5). During plating the x axis
19 of the jig is oscillated plus and minus 25° about the y
20 axis which is perpendicular to the x axis with a cycle
21 time of 3 minutes. Simultaneously, the jig is rotated
22 about the x axis unidirectionally and through 360° with
23 a cycle time of 10 minutes for a complete revolution.
24 However the rotation about the x axis is intermittent
25 with 10 second stop periods being interspersed with 3
26 second go periods.

27 Plating is carried out with a current density of
28 0.3 amps per square decimetre for a period of 24 hours
29 to produce a coating thickness of between 50 and 125
30 micrometres.

31 A coating of excellent qualities is produced
32 covering the aerofoil portion and the root and shroud
33 platforms and having a weight fraction of incorporated

1 powder of 0.27. After removal of the coated blades
2 from the jig, the masking is removed and and the blades
3 are heat treated to effect some interdiffusion between
4 the matrix and the particles and to effect some degree
5 of alloying.

6 Attention is directed to application number
7 9207448.3 which has been divided from this application
8 and which claims a process for the production by
9 electrolytic or electroless deposition on a workpiece
10 of a composite coating comprising a metal matrix
11 containing particles, the particles being codeposited
12 with the metal from a solution in which the particles
13 are insoluble, comprising inducing circulation in the
14 solution generally upwards in one zone and generally
15 downwards in a second zone, locating the workpiece in
16 the second zone and rotating the workpiece about a
17 first axis having a horizontal component, and rotating
18 the workpiece about a second axis which is non-parallel
19 with the first.

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Claims:

1. A process for the production by electrolytic or electroless deposition on a workpiece of a composite coating comprising a metal matrix containing particles, the particles being codeposited with the metal from a solution in which the particles are insoluble, comprising inducing circulation in the solution generally upwards in one zone and generally downwards in a second zone, locating the workpiece in the second zone, and rotating the workpiece about an axis having a horizontal component, the rotational cycle including periods of higher angular velocity and periods of lower angular velocity.

2. A process as claimed in Claim 1 in which the rotation is alternately stop and go.

3. A process as claimed in Claim 1 the process being substantially as described herein with reference to the accompanying drawings.