

A method of coating a sheet of steel

The present invention relates to a method of coating a
5 sheet of steel and to a coating for a sheet of steel and relates particularly, but not exclusively, to a method of coating a surface of a weight bearing sheet of steel for use on an aircraft carrier.

Ships, such as aircraft carriers, are commonly made from
10 steel including the uppermost deck surface that acts as the aircrafts' takeoff and landing runway. These deck surfaces are commonly protected by applying a layer of organic paint. However, such paint is unable to withstand the gas-wash produced during the takeoff and landing of aircraft that use jet engines
15 to facilitate a vertical takeoff or landing or short takeoff and vertical landing (STOVL). This gas-wash can result in a change of surface temperature from ambient to 2000°C causing a patch of the paintwork to be burnt away on each such manoeuvre. Such damage then makes a deck surface vulnerable to corrosion.

20 A surface coating is required that is able to deal with the rapid change in temperature including starting from ambient temperatures in a range of -50° C to +50° C. The coating must provide a nonslip or anti-skid surface allowing it to be safely walked on, it must be sufficiently robust to withstand the force
25 applied to it during takeoff and landing and be easily repairable in the event of damage.

Preferred embodiments of the present invention seek to overcome the above described disadvantages of the prior art.

Summary

30 In one aspect, the present invention provides a method of coating a sheet of steel comprising the steps:- preparing a surface of a sheet of steel that is to be coated; applying a

first metal deposition coating to said sheet of steel, said first coating comprising aluminium; applying a second metal deposition coating to said first coating, said second coating comprising aluminium and a least one first doping material; and applying a barrier coating to said second metal deposition coating and characterised in that said second metal deposition coating is applied in a plurality of stages including a first stage and a second stage and wherein a particle accelerator used in the coating applications operates so as to accelerate the particles more in the first stage than the second stage so that a surface produced in said first stage has a surface roughness less than a surface roughness produced in said second stage. In another aspect, the present invention provides a coating for a sheet of steel, the coating comprising:- a first metal deposition coating comprising aluminium and applied to a prepared surface of a sheet of steel; a second metal deposition coating comprising aluminium and at least one first doping material and applied to said first metal deposition coating; a barrier coating applied to said second metal deposition coating, wherein said second metal deposition coating is applied in a plurality of stages including a first stage and a second stage and wherein a surface produced in said first stage has a surface roughness less than a surface roughness produced in said second stage. In yet another aspect, the present invention provides a sheet material comprising:- a sheet of steel material; and a coating as described herein applied to said sheet of steel material. In yet another aspect, the present invention provides an article comprising at least one sheet material as described herein.

Description

According to an aspect of the present invention there is provided a method of coating a sheet of steel comprising the steps:-

preparing a surface of a sheet of steel that is to be coated;

applying a first metal deposition coating to said sheet of steel,
said first coating comprising aluminium;

5 applying a second metal deposition coating to said first
coating, said second coating comprising aluminium and at least
one first doping material; and

applying a barrier coating to said second metal deposition
coating.

10 By applying, to a sheet of steel, a first coating of
aluminium, a second coating of aluminium plus a doping material
and a barrier coating, a series of advantages are provided. The
sheet material is protected from corrosion and provides a
non-slip or anti-skid surface which is safe to walk on and provide
15 suitable friction resistant surface to operate an aircraft from.
The surface can be painted and yet is sufficiently resistant to
rapid changes in temperatures that the gas wash from a vertical
takeoff aircraft will not damage the surface or the steel. The
surface also provides sufficient frictional resistance to allow
the takeoff on landing of other aircraft.

20 In a preferred embodiment the surface of said sheet of
steel is prepared by grit blasting.

By grit blasting the steel surface a substantially oxide
free and suitably rough surface is created which ensures a secure
bond between the steel of the sheet material and the aluminium
25 of the first coating.

In another preferred embodiment grit blasting uses a grit
comprising brown fused alumina which is suitably angular and
robust to provide the required profile to optimise adhesion of
the aluminium of the first coating.

30 In a preferred embodiment the first coating further
comprises at least one second doping material which enhances the

corrosion resistance of the first coating and/or facilitates the ease of repair.

In another preferred embodiment second doping material comprises at least one of zinc, molybdenum, gallium, tin and
5 indium. The addition of the dopants extends the life of the sacrificial characteristics of the first coating layer in marine environments and increases the compatibility of the first coating with the repair regime.

In a further preferred embodiment first metal deposition
10 coating is applied to a thickness of between 75 and 200 μm .

The second metal deposition coating may be applied in a plurality of stages including a first stage and a second stage and wherein a particle accelerator used in the coating applications operates so as to accelerate the particles more in
15 the first stage than the second stage.

The second metal deposition coating may also be applied in a plurality of stages including a first stage and a second stage and wherein a particle accelerator used in the coating applications operates so that a surface produced in said first
20 stage has a surface roughness less than a surface roughness produced in said second stage.

By applying the second metal deposition coating in a plurality of stages with lower acceleration of the particles in the second stage thereby leading to greater roughness of the
25 resulting surface, the advantage is provided that the bond between the first metal deposition coating and the second metal deposition coating are secure (due to the increased particle velocity on impact in the first stage) but the uppermost surface of the second metal deposition coating is sufficiently rough
30 (due to decreased particle velocity on impact in the second stage) to assist in the provision of a nonslip or anti-skid surface.

In another preferred embodiment the second metal deposition coating is applied to a thickness of between 150 and 300 μm .

In a preferred embodiment the barrier coating comprises an inorganic heat resistant coating material.

5 By using an inorganic heat resistant coating material for the barrier coating, the advantage is provided that the barrier coating assists in the protection of the first and second metal deposition coatings and the high temperatures, resultant from jet gas wash, do not damage the barrier coating. As a result,
10 the coating of the present invention can be regarded as intumescent.

In another preferred embodiment the barrier coating comprises a potassium silicate coating material.

A potassium silicate coating provides the above described
15 advantages and can be applied at a convenient thickness.

In a further preferred embodiment the barrier coating is applied to a thickness of between 5 and 25 μm .

By providing a barrier coating of the above thickness, the advantage is provided that the barrier coating follows, and
20 substantially reproduces, the profile of second metal deposition coating thereby assisting in the creation of the nonslip surface.

In a preferred embodiment at least one of said first and second metal deposition coatings are applied using at least one
25 of the metal deposition techniques of arc spray, wire spray, twin wire arc spray, air plasma and cold spray.

According to another aspect of the present invention there is provided a coating for a sheet of steel, the coating comprising:-

30 a first metal deposition coating comprising aluminium and applied to a prepared surface of a sheet of steel;

a second metal deposition coating comprising aluminium and at least one first doping material and applied to said first metal deposition coating;

a barrier coating applied to said second metal deposition
5 coating.

The first coating may further comprise at least one second doping material.

The second doping material may comprise at least one of zinc, molybdenum, Gallium, tin and indium.

10 In a preferred embodiment the first metal deposition coating has a thickness of between 75 and 200 μm .

The first doping material may comprise at least one of titanium, chromium, manganese, boron, aluminium oxide, titanium oxide, chromium oxide, manganese oxide, boron oxide, boron
15 nitride, boron carbide and tungsten carbide.

In a preferred embodiment the second metal deposition coating is applied in a plurality of stages including a first stage and a second stage and wherein a surface produced in said first stage has a surface roughness less than a surface roughness
20 produced in said second stage.

In another preferred embodiment the second metal deposition coating is applied to a thickness of between 150 and 300 μm .

In a preferred embodiment the barrier coating comprises an inorganic heat resistant coating material.

25 In another preferred embodiment the barrier coating comprises a potassium silicate coating material.

In a further preferred embodiment the barrier coating is applied to a thickness of between 5 and 25 μm .

According to a further aspect of the present invention
30 there is provided a sheet material comprising:-

a sheet of steel material; and

a coating as set out above applied to said sheet of steel material.

In a preferred embodiment the steel comprises hardened steel.

- 5 In another preferred embodiment the steel comprises carbon manganese steel.

According to another aspect of the present invention there is provided an article comprising at least one sheet material as set out above.

- 10 In a preferred embodiment the sheet material forms a weight bearing surface.

- In another preferred embodiment the article is any of a helicopter landing platform, a submarine, an oil rig, a chemical processing plant, an energy production plant, a shipping
15 container and a munitions box.

According to a further aspect of the present invention there is provided an apparatus for applying a coating to a sheet of steel, the apparatus comprising:-

- a frame for supporting a plurality of metal deposition coating
20 applicators;

applicator moving means for moving said applicators relative to said frame;

- at least one applicator for applying at least one first metal deposition coating and at least one second metal deposition
25 coating to a sheet of steel; and

at least one processor for controlling said applicators and said applicator moving means.

By providing an apparatus described above, the advantage is provided that large surfaces of sheet material, for example

the deck of an aircraft carrier, can be coated accurately and evenly producing a surface to a consistent standard.

In a preferred embodiment the applicator uses at least one of the metal deposition techniques of arc spray, wire spray,
5 twin wire arc spray, air plasma and cold spray.

The apparatus may comprise a plurality of applicators for applying at least one first metal deposition coating and at least one second metal deposition coating to a sheet of steel.

Preferred embodiments of the present invention will now be
10 described, by way of example only, and not and in any limitative sense with reference to the accompanying drawings in which:-

Figure 1 is a flowchart showing a method of the present invention;

Figure 2 is a schematic sectional representation of a sheet
15 material and coating of the present invention;

Figure 3 is a micrograph image of a prepared surface of sheet material used in the present invention;

Figure 4 is a micrograph of a cross-section of a prepared surface of sheet material used in the present invention;

20 Figure 5 is a micrograph of a cross-section of a prepared surface of sheet material not suitable for use in the present invention;

Figure 6 is a flowchart showing a method of the present invention;

25 Figure 7 is a perspective view of an apparatus for applying the coating of present invention; and

Figure 8 is another perspective view of the apparatus of figure 7.

Referring to figures 1 and 2, a method of applying a coating 10 onto a sheet of steel 12 is undertaken in a series of steps set out in figures 1 and 6, with figure 1 representing a simplified version of the more complete process shown in figure 6. At the start of the process a sheet of steel material 12 is prepared in order to receive the coating 10 that will be applied to at least one surface thereof. The thickness of the sheet of steel is dependent upon the application for which it is to be used and is therefore not a constraint or limitation of this invention. Furthermore, the term sheet refers to a single or multiple sheets of steel that are joined together and it is not a limitation of this invention that the sheets form a planar or substantially planar surface. The purpose of the coating is to create a protective nonslip or anti-skid surface to the steel. The steel is for use in any suitable weight bearing situation carrying the weight of, for example, a person, vehicle or aircraft.

The primary functions of the surface preparation (indicated at 14 on figures 1 and 6) are to expose a substantially oxide free surface of the steel and to create sufficient surface roughness to ensure secure bonding between the steel 12 and coating 10. An example of such a surface preparation technique is grit blasting (indicated at 16) in which a grit, preferably brown fused alumina, is accelerated in a stream of compressed air at a pressure of greater than 80 psi and directed at the sheet steel at an angle between 45° and 90° to the surface being prepared.

An inspection takes place at step 18 and a pass or fail is determined at step 20. The step of inspection may include examining a micrograph of the prepared surface and an acceptable surface micrograph at 100 times magnification is shown in figure 3 with the sharp edges shown therein providing an indication of a surface that will create a good bond to the

coating that will be applied thereto. Figures 4 and 5 are also micrographs (at 100 times magnification) showing a cross-section of the grit blasted surface. Figure 4 shows an example of an acceptable grit blasted surface and figure 5 shows an example of an unacceptable surface due to having insufficient roughness. The table below set out the preferred critical roughness parameters for the blasted surface, the roughness being measured using roughness measuring techniques familiar to a person skilled in the art.

Parameter	Description	Acceptable Range (μm)
R _a	The mean of the absolute values and describes the average roughness	≥ 4 (normally 4-5.5)
R _p	The maximum peak height	≥ 15
R _{ku}	The average sharpness of the peaks	≥ 3
R _{sm}	The mean width of the profile peak elements	≤ 500
R _t	The maximum peak to valley height in the sampling length	30 - 60

Prior to the grit blasting at step 16, other surface preparation techniques may be applied. These include degreasing and paint removal and the latter may be undertaken using grit blasting but with another grit such as shot or aggregate. The surface may also be tested for grease and for the presence of chloride using a chloride indicator tape or similar techniques familiar to a person skilled in the art.

Following the surface preparation in step 14, metal deposition is undertaken at step 22. This metal deposition is undertaken in two different coatings with two different compositions of metal being deposited consecutively onto the steel 12. A first metal deposition coating 24 is applied at step 25 and comprises at least aluminium. The first metal deposition coating 24 may include a doping component, including, but not limited to, metals such as zinc, molybdenum, gallium,

tin and indium. The first metal deposition coating 24 is applied by arc spraying although other metal deposition/spraying processes are also acceptable including, but not limited to, wire spray, twin wire arc spray, air plasma and cold spray. The first metal deposition coating typically has a thickness of between 75 and 200 μm . The first metal deposition coating is preferably applied as a series of layers bypassing the spray gun over the same surface a number of times.

Once the first metal deposition coating 24 has been applied a second metal deposition coating 26 is applied (at step 27) on top of the first coating 24. The second metal deposition coating comprises aluminium and at least one other doping component, including, but not limited to, metals such as titanium, chromium, manganese, boron, aluminium oxide, titanium oxide, chromium oxide, manganese oxide, boron oxide, boron nitride, boron carbide and tungsten carbide. The second metal deposition coating 26 is applied using any of the same techniques used to apply the first metal deposition coating 24. The second metal deposition coating typically has a thickness of between 150 and 300 μm and is applied in two stages. The two stages preferably use the same metal combination but can be distinguished by a difference in the acceleration of the metal particles from the spray gun as the spray is applied. In the first stage of the application, producing the first stage 28 of second coating 26, the spray particles are accelerated from the spray gun at a faster rate than those producing the second stage 30 of second coating 26. In the first stage the increased momentum of the fast-moving particles results in secure adhesion between the second coating 26 and first coating 24 and high density. However, the resultant temporary surface (indicated at 32) at the end of the first stage of the second coating does not have sufficient roughness to provide a good nonslip or anti-skid surface. By slowing down and reducing the momentum of the particles in the second stage (by reducing the pressure of the

accelerant gas in the spray gun by roughly half) a rougher surface (indicated at 34) is produced.

Once the first and second metal deposition coatings have been applied and inspection takes place at step 29 and a pass fail is determined at step 31. The inspection can include a visual inspection, surface roughness measurements and a bend test (where a sample of steel, not forming part of the main surface being protected, is taken and bent using a predetermined force around a predetermined diameter to ensure good adhesion between the metal deposition coatings and the steel).

The coating 10 is completed by the application (at step 33) of a barrier coating 36. The barrier coating is an inorganic heat resistant material such as a potassium silicate sealant. The sealant acts as a barrier preventing oxidisation of the aluminium and is applied in a layer that is thinner than the first and second metal deposition coatings at between 5 and 25 μm thick. This thickness is sufficiently small that the roughness of the upper surface 34 of the second metal deposition coating 26 is retained thereby providing a good nonslip surface. The barrier coating can be applied by brush, roller, spray gun (HVLP, High velocity, low pressure) or dipping for smaller surfaces. The barrier coating 36 can include a pigment in order to provide a base coat colour as required.

Once the barrier coating has been applied a final inspection step takes place at 35 and a pass fail is determined at 37. If required, further barrier coatings containing other pigments to produce other colours can be applied to the surface of the barrier coating to give line marking or other demarcation as required.

Spray guns of the type described above can be operated manually to apply the metal deposition coatings. However, when working over large surface areas it is preferable to use a

robotic device of the type shown in figures 7 and 8. The apparatus includes a frame 50 which is placed onto sheet material 12 and is manoeuvrable via wheels 52. An applicator, in the form of spray gun 54, is provided to apply the first metal deposition coating and the second metal deposition coating in consecutive applications. However, the applicator could alternatively include two or more spray guns to apply the separate metal deposition coatings and most preferably includes three spray guns. The first spray gun applies the first metal deposition coating, the second spray gun applies the first stage of the second metal deposition coating and the third gun applies the second stage of the second metal deposition coating. The applicator is moved relative to frame 50 using an applicator moving means in the form of robotic arm 56. It will be apparent to person skilled in the art that other applicator moving means could be used to control the movement of the applicator relative to the frame, such as a flat-bed scanner. The movement of the robotic arm 56 and use of the spray gun 54 is controlled by a processor (not shown). The processor enables the even application of the coatings and can ensure that at the edges of the patch of coating 10 (see figure 8) are feathered, by controlling the speed of movement of the arm and/or rate of deposition of the metal coating, so that patches of coating 10 can be separately formed and a consistent coating be applied to the whole surface of the sheet steel material 12.

The sheet material is suitable for use in any of the following applications, which are provided by way of example only and not as a definitive list, a helicopter landing platform, a submarine, an oil rig, a chemical processing plant, an energy production plant, a shipping container and a munitions box. It is generally the case that the application in which the coating is being applied to the sheet of steel is already built when the coating is applied. For example, if the coating is being applied

to the deck of an aircraft carrier, the coating is applied once the ship has been constructed.

It will be appreciated by persons skilled in the art that the above embodiments have been described by way of example only and not in any limitative sense, and that various alterations and modifications are possible without departure from the scope of the protection which is defined by the appended claims.

Claims

1. A method of coating a sheet of steel comprising the steps:-

preparing a surface of a sheet of steel that is to be coated;

5 applying a first metal deposition coating to said sheet of steel, said first coating comprising aluminium;

applying a second metal deposition coating to said first coating, said second coating comprising aluminium and a least one first doping material; and

10 applying a barrier coating to said second metal deposition coating and characterised in that said second metal deposition coating is applied in a plurality of stages including a first stage and a second stage and wherein a particle accelerator used in the coating applications operates so as to accelerate
15 the particles more in the first stage than the second stage so that a surface produced in said first stage has a surface roughness less than a surface roughness produced in said second stage.

2. A method according to claim 1, wherein said surface of
20 said sheet of steel is prepared by grit blasting.

3. A method according to claim 2, wherein said grit blasting uses a grit comprising brown fused alumina.

4. A method according to any preceding claim, wherein said first coating further comprises at least one second doping
25 material.

5. A method according to claim 4, wherein said second doping material comprises at least one of zinc, molybdenum, Gallium, tin and indium.

6. A method according to any preceding claim, wherein said first metal deposition coating is applied to a thickness of between 75 and 200 μm .

7. A method according to any preceding claim, wherein said first doping material comprises at least one of titanium, chromium, manganese, boron, aluminium oxide, titanium oxide, chromium oxide, manganese oxide, boron oxide, boron nitride, boron carbide and tungsten carbide.

8. A method according to any preceding claim, wherein said second metal deposition coating is applied to a thickness of between 150 and 300 μm .

9. A method according to any preceding claim, wherein said barrier coating comprises an inorganic heat resistant coating material.

10. A method according to any preceding claim, wherein said barrier coating comprises a potassium silicate coating material.

11. A method according to any preceding claim, wherein said barrier coating is applied to a thickness of between 5 and 25 μm .

12. A method according to any preceding claim, wherein at least one of said first and second metal deposition coatings are applied using at least one of the metal deposition techniques of arc spray, wire spray, twin wire arc spray, air plasma and cold spray.

13. A coating for a sheet of steel, the coating comprising:-

a first metal deposition coating comprising aluminium and applied to a prepared surface of a sheet of steel;

a second metal deposition coating comprising aluminium and at least one first doping material and applied to said first metal deposition coating;

a barrier coating applied to said second metal deposition coating, wherein said second metal deposition coating is applied in a plurality of stages including a first stage and a second stage and wherein a surface produced in said first stage has a surface roughness less than a surface roughness produced in said second stage.

14. A coating according to claim 13, wherein said first coating further comprises at least one second doping material.

15. A coating according to claim 14, wherein said second doping material comprises at least one of zinc, molybdenum, Gallium, tin and indium.

16. A coating according to anyone of claims 13 to 15, wherein said first metal deposition coating has a thickness of between 75 and 200 μm .

17. A coating according to anyone of claims 13 to 16, wherein said first doping material comprises at least one of titanium, chromium, manganese, boron, aluminium oxide, titanium oxide, chromium oxide, manganese oxide, boron oxide, boron nitride, boron carbide and tungsten carbide.

18. A coating according to anyone of claims 13 to 17, wherein said second metal deposition coating is applied to a thickness of between 150 and 300 μm .

19. A coating according to anyone of claims 13 to 18, wherein said barrier coating comprises an inorganic heat resistant coating material.

20. A coating according to anyone of claims 13 to 19, wherein said barrier coating comprises a potassium silicate coating material.

21. A coating according to anyone of claims 13 to 20, wherein said barrier coating is applied to a thickness of between 5 and 25 μm .

22. A sheet material comprising:-

a sheet of steel material; and

a coating according to any of claims 13 to 24 applied to said sheet of steel material.

5 23. A sheet material according to claim 22, wherein said steel comprises hardened steel.

24. A sheet material according to claim 22 or 23, wherein said steel comprises carbon manganese steel.

10 25. An article comprising at least one sheet material according to any of claims 22 to 24.

26. An article according to claim 25, wherein said sheet material forms a weight bearing surface.

15 27. An article according to claim 25 or 26, wherein said article is any of a helicopter landing platform, a submarine, an oil rig, a chemical processing plant, an energy production plant, a shipping container and a munitions box.