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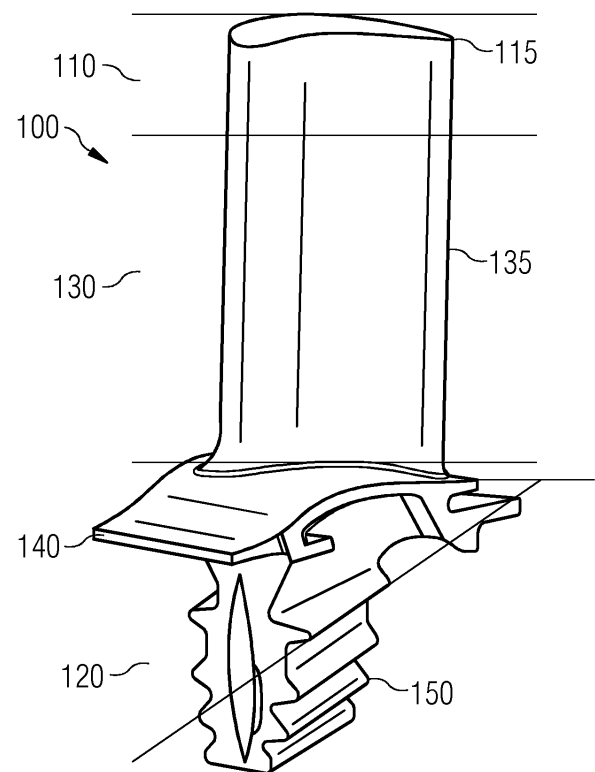
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(54) **IMPROVEMENTS RELATING TO COATINGS FOR METAL ALLOY COMPONENTS**

(57) A component, such as a turbine aerofoil, comprising an anti-corrosion coating is disclosed. The component comprises a substrate coated with an MCrAlX layer and an upper coating layer. The upper coating layer has an aluminium-rich zone in a first region of the component, for example in a top region of a turbine aerofoil comprising a tip of the turbine aerofoil. The upper coating layer has a chromium-rich zone in a second region of the component, for example in a bottom region of a turbine aerofoil between a platform and a root of the aerofoil. These specific upper coating layers may provide resistance to Type I hot corrosion in the first region of the component and resistance to Type II hot corrosion in the second region. A method of forming such a coating on a component and a cold spraying apparatus for applying such a coating are also disclosed.

FIG 4



Description

[0001] The present disclosure relates to components manufactured from metal alloys, the components comprising coatings which improve corrosion resistance, and to methods of providing said coatings.

[0002] In particular the disclosure is concerned with components, for example turbine aerofoils, having a coating which has an aluminium-rich coating in one region of the component and a chromium-rich coating in a different region of the component.

Background

[0003] Turbines operate at high temperatures to maximise their fuel efficiency and performance. Operating at high temperatures exposes the components of turbines to hot corrosion processes which can cause catastrophic damage to the turbine components during use. Such damage necessitates costly repairs or replacement of the turbine components. Hot corrosion processes can be classified as Type I (corrosion at 800-950 °C) and Type II (corrosion at 600-800°C). These corrosion processes are caused by salt contaminants such as sodium and potassium salts and V_2O_5 which are drawn into the turbine with the air intake and which then dissolve protective surface oxides due to the low melting point deposits which they normally produce. Some components, for example nickel alloy turbine aerofoils, can experience different temperatures at different regions of the component. It is therefore possible for one region of a component to experience Type I hot corrosion and another region of the component to experience Type II hot corrosion. For example, turbine aerofoils can be exposed to temperatures of 800-950 °C or greater at the aerofoil tip which therefore may suffer Type I hot corrosion, whereas the aerofoil bottom region under the platform may be exposed to temperatures of 600-650 °C and therefore may suffer Type II hot corrosion.

[0004] There is no known single coating which is satisfactorily resistant to both Type I and Type II hot corrosion processes to which turbine aerofoils are exposed in use.

[0005] Some known methods for applying coatings to protect components from these corrosion processes involve coating such components using pack aluminide, chemical vapour deposition, high velocity oxy-fuel and electron beam physical vapour deposition. These coating processes involve numerous complicated procedures to finally form the coatings and may result in significant thermal distortion of the component due to the high temperatures employed.

[0006] Also with these known coating processes, it is not possible to coat various regions of a component with different coatings without using sequential coating steps or masking off some regions of the component while a different coating is being applied to other regions of the component. These sequential coating steps or masking

operations add significantly to the cost of coating such components.

[0007] Hence a coating and coating method which can efficiently provide a component with protection against Type I and Type II hot corrosion in different regions of the component is highly desirable.

Summary

[0008] According to the present disclosure there is provided a coating, a method of coating a component and an apparatus for coating a component as set forth in the appended claims. Other features of the invention will be apparent from the dependent claims, and the description which follows.

[0009] According to a first aspect of the present invention, there is provided a component comprising a substrate, an MCrAIX layer on the substrate and an upper coating layer on the MCrAIX layer; wherein:

in a first region of the component, the upper coating layer is an aluminium-rich region of the upper coating layer; and

in a second region of the component, the upper coating layer is a chromium-rich region of the upper coating layer.

[0010] In the component of this first aspect, the substrate forms the bulk of the component and the MCrAIX and upper coating layers together form a protective coating on the component. The MCrAIX layer is arranged between the substrate and the upper coating layer and suitably the upper coating layer provides an outermost layer of the component which is exposed to the environment outside of the component. Suitably the MCrAIX layer completely covers and surrounds the substrate. Suitably the upper coating layer completely covers and surrounds the MCrAIX layer.

[0011] MCrAIX is a commonly used term in the art to refer to alloys comprising a base metal (M), chromium, aluminium and at least one further metal (X). The base metal (M) is commonly cobalt, nickel or a mixture of both cobalt and nickel. The at least one further metal is selected from one or more of yttrium, hafnium, zirconium, silicon and boron, suitably yttrium. MCrAIX layers are used as coatings, or as one of several coatings, in components such as turbine components to provide corrosion and/or temperature resistance.

[0012] The upper coating layer is an aluminium-rich region of the upper coating layer in the first region of the component and a chromium-rich region of the upper coating layer in the second region of the component. Therefore the upper coating layer has a different composition in the first region compared to the second region.

[0013] Suitably the aluminium-rich region is enriched in aluminium compared to the substrate. Suitably the aluminium-rich region is enriched in aluminium compared

to the MCrAlX layer. Suitably the aluminium-rich region is enriched in aluminium compared to the chromium-rich region. Suitably the aluminium-rich region is enriched in aluminium compared to each of the substrate, the MCrAlX layer and the chromium-rich region. The term "enriched in aluminium" may refer to said layer region comprising a higher wt% of aluminium than the other layer and/or regions referred to.

[0014] Suitably the chromium-rich region is enriched in chromium compared to the substrate. Suitably the chromium-rich region is enriched in chromium compared to the MCrAlX layer. Suitably the chromium-rich region is enriched in chromium compared to the aluminium-rich region. Suitably the chromium-rich region is enriched in chromium compared to each of the substrate, the MCrAlX layer and the aluminium-rich region. The term "enriched in chromium" may refer to said layer region comprising a higher wt% of chromium than the other layer regions referred to.

[0015] The combination of an aluminium-rich upper coating region and a chromium-rich upper coating region in different regions of the component provide different types of hot corrosion resistance to the different regions of the component. The aluminium-rich upper coating region provides resistance to Type I hot corrosion due to protective alumina scales being formed at the temperatures which cause Type I hot corrosion. The alumina scales provide the desired protection of the component (the substrate and other coating layer(s)) against the corrosion process. The chromium-rich upper coating region provides resistance to Type II hot corrosion due to protective chromia scales being formed at the temperatures which cause Type II hot corrosion. The chromia scales provide the desired protection of the component (the substrate and other coating layer(s)) against the corrosion process. Therefore the component of this first aspect has an upper coating layer which provides resistance to different types of hot corrosion in different regions of the component, according to which is the dominant corrosion process in those different regions of the component in use. Specifically the upper coating layer provides resistance to Type I hot corrosion in the first region of the component and resistance to Type II hot corrosion in the second region.

[0016] The inventors have found from strain to crack experiments on aluminium containing coatings that at relatively high operating temperatures of a region of a component (for example 800-950 °C as experienced by a turbine aerofoil tip in use) the ductility of the majority of known coating systems used for oxidation/corrosion resistance is typically greater than the ductility of the substrate of the component. Therefore such coatings are not susceptible to crack initiation in the coating and subsequent failure of the blade in said region of the component. However, the inventors have also found that at relatively low temperatures of a region of a component (for example 600-800°C as experienced by a turbine bottom region in use) the ductility of the majority of known coating systems

used for oxidation/corrosion resistance is typically lower than the ductility of the substrate of the component. Therefore such coatings are susceptible to crack initiation and subsequent failure of the blade in said region of the component.

[0017] The inventors have found that the strain to crack value of an upper coating layer at such relatively low temperatures can be increased by using a relatively low amount of aluminium and a relatively high proportion of chromium. In regions of the component wherein the strain to crack value is not as important to the performance of the component, a higher aluminium content can be used to benefit from the corrosion protection provided by alumina scales, in use.

[0018] The inventors have therefore found that improved strain to crack resistance may be obtained by using the different upper coating layer compositions in different regions of the component of the present invention, as described herein. These different compositions of upper coating layers can provide such components with appropriate chemical and mechanical properties in appropriate regions of the component, which take into account the competing requirements of the component and coating in said regions. The coating of the component of this first aspect may therefore be referred to as a tailored or functionally graded coating.

[0019] Suitably the substrate is a nickel alloy, for example a nickel superalloy. Suitably the MCrAlX layer is a nickel alloy. Suitably the upper coating layer is a nickel alloy. Suitably the MCrAlX layer and the upper coating layer are nickel alloys. Suitably the substrate, the MCrAlX layer and the upper coating layer are all nickel alloys.

[0020] In the MCrAlX layer, M is suitably cobalt and nickel. Therefore the MCrAlX layer may be an MCrAlY layer suitably comprising cobalt, nickel, chromium, aluminium and yttrium.

The aluminium-rich region of the upper coating layer

[0021] Suitably the aluminium-rich region is a nickel alloy. Suitably the aluminium-rich region comprises nickel and from 20 to 40 wt% aluminium, suitably from 20 to 35 wt% aluminium, suitably from 25 to 35 wt% aluminium, for example approximately 32 wt% aluminium or 32 wt% aluminium.

[0022] Suitably the aluminium-rich region also comprises chromium. Suitably the aluminium-rich region comprises nickel, aluminium and from 10 to 20 wt% chromium, suitably from 10 to 20 wt% chromium, suitably from 12 to 18 wt% chromium, suitably from 13 to 16 wt% chromium, for example approximately 15 wt% chromium or 15 wt% chromium.

[0023] Suitably the aluminium-rich region is a nickel alloy comprising from 10 to 20 wt% chromium and from 20 to 40 wt% aluminium, suitably from 12 to 18 wt% chromium and from 25 to 35 wt% aluminium, suitably from 13 to 16 wt% chromium and from 30 to 35 wt% aluminium. Suitably the aluminium-rich region is a nickel alloy com-

prising approximately 15 wt% chromium and approximately 32 wt% aluminium. Suitably the aluminium-rich region is a nickel alloy comprising 15 wt% chromium and 32 wt% aluminium.

[0024] Suitably the aluminium-rich region comprises nickel, chromium and aluminium, with chromium and aluminium being present in the above amounts and nickel providing the remaining wt% of the aluminium-rich region.

[0025] Suitably the aluminium-rich region consists essentially of nickel, chromium and aluminium, with chromium and aluminium being present in the above amounts and nickel providing the remaining wt% of the aluminium-rich region.

[0026] In some embodiments, the aluminium-rich region may comprise one or more of platinum, rhodium, yttrium, hafnium and zirconium. For example, the aluminium-rich region may comprise platinum and at least one of yttrium, hafnium and zirconium, suitably platinum and yttrium.

[0027] In said embodiments, the aluminium-rich region may comprise from 5 to 15 wt% platinum, suitably from 8 to 12 wt% platinum, suitably from 9 to 11 wt% platinum. Suitably the aluminium-rich region comprises approximately 10 wt% platinum, suitably 10 wt% platinum.

[0028] In said embodiments, the aluminium-rich region may comprise from 0.01 to 1 wt% yttrium, hafnium or zirconium, suitably from 0.05 to 0.5 wt% yttrium, hafnium or zirconium, suitably from 0.05 to 0.2 wt% yttrium, hafnium or zirconium. Suitably the aluminium-rich region comprises approximately 0.1 wt% yttrium, hafnium or zirconium, suitably 0.1 wt% yttrium, hafnium or zirconium. Suitably the aluminium-rich region comprises yttrium in the above amounts.

[0029] In said embodiments, the aluminium-rich region may comprise from 25 to 40 wt% aluminium, suitably from 25 to 35 wt% aluminium, suitably from 30 to 35 wt% aluminium, for example approximately 32 wt% aluminium or 32 wt% aluminium.

[0030] In said embodiments, the aluminium-rich region may comprise from 1 to 10 wt% chromium, suitably from 2 to 8 wt% chromium, suitably from 4 to 6 wt% chromium, for example approximately 5 wt% chromium or 5 wt% chromium.

[0031] In said embodiments, the aluminium-rich region is suitably a nickel alloy comprising from 2 to 8 wt% chromium and from 20 to 40 wt% aluminium, from 5 to 15 wt% platinum and from 0.01 to 1 wt% yttrium, hafnium or zirconium. Suitably the aluminium-rich region is a nickel alloy comprising 5 wt% chromium, 32 wt% aluminium, 10 wt% platinum and 0.1 wt% yttrium, hafnium or zirconium, suitably yttrium.

[0032] In said embodiments, the aluminium-rich region may comprise nickel, chromium, aluminium, platinum and yttrium, with chromium, aluminium, platinum and yttrium being present in the above amounts and nickel providing the remaining wt% of the aluminium-rich region.

[0033] In said embodiments, the aluminium-rich region

may consist essentially of nickel, chromium, aluminium, platinum, lanthanum and yttrium, with chromium, aluminium, platinum and yttrium being present in the above amounts and nickel providing the remaining wt% of the aluminium-rich region.

[0034] The aluminium-rich region may comprise tantalum, suitably from 0.05 to 0.5 wt% tantalum, suitably from 0.05 to 0.2 wt% tantalum. Tantalum may improve the oxidation resistance of the aluminium-rich region in the first region of the component.

[0035] The aluminium-rich region of the upper coating layer in the first region may comprise from 0.01 to 5 wt% silicon, suitably from 1 to 4 wt% silicon, suitably from 2 to 3 wt% silicon, suitably approximately 2.5 wt%, suitably 2.5 wt%. Such amounts of silicon in the aluminium-rich region may improve cyclic oxidation resistance, in particular at temperatures of up to 1000 °C experienced by a turbine aerofoil tip, in use.

20 *The chromium-rich region of the upper coating layer*

[0036] Suitably the chromium-rich region is a nickel alloy. Suitably the chromium-rich region comprises nickel and from 40 to 60 wt% chromium, suitably from 40 to 60 wt% chromium, suitably from 50 to 60 wt% chromium, for example approximately 60 wt% chromium or 60 wt% chromium.

[0037] Suitably the chromium-rich region also comprises aluminium. Suitably the chromium-rich region comprises nickel, chromium and from 15 to 20 wt% aluminium, suitably from 17 to 20 wt% aluminium, suitably from 18 to 20 wt% aluminium, for example approximately 20 wt% aluminium or 20 wt% aluminium.

[0038] Suitably the chromium-rich region is a nickel alloy comprising from 50 to 60 wt% chromium and from 15 to 20 wt% aluminium, suitably from 55 to 60 wt% chromium and from 18 to 20 wt% aluminium. Suitably the chromium-rich region is a nickel alloy comprising approximately 60 wt% chromium and approximately 20 wt% aluminium. Suitably the chromium-rich region is a nickel alloy comprising 60 wt% chromium and 20 wt% aluminium.

[0039] Suitably the chromium-rich region comprises nickel, chromium and aluminium, with chromium and aluminium being present in the above amounts and nickel providing the remaining wt% of the chromium-rich region.

[0040] Suitably the chromium-rich region consists essentially of nickel, chromium and aluminium, with chromium and aluminium being present in the above amounts and nickel providing the remaining wt% of the chromium-rich region.

The intermediate region

[0041] Suitably the component comprises an intermediate region wherein the upper coating layer of the intermediate region has an aluminium content lower than the aluminium-rich region and higher than the chromium-rich region; and has a chromium content higher than the alu-

minium-rich region and lower than the chromium-rich region.

[0042] Suitably the intermediate region is located in the component between the first region and the second region.

[0043] The upper coating layer of the intermediate region is suitably a nickel alloy. Suitably the upper coating layer of the intermediate region comprises nickel and from 5 to 15 wt% chromium, suitably from 7 to 13 wt% chromium, suitably from 8 to 12 wt% chromium, for example approximately 10 wt% chromium or 10 wt% chromium.

[0044] Suitably the upper coating layer of the intermediate region also comprises aluminium. Suitably the upper coating layer of the intermediate region comprises nickel, chromium and from 15 to 25 wt% aluminium, suitably from 18 to 23 wt% aluminium, suitably from 20 to 22 wt% aluminium, for example approximately 21 wt% aluminium or 21 wt% aluminium.

[0045] Suitably the upper coating layer of the intermediate region is a nickel alloy comprising from 5 to 15 wt% chromium and from 15 to 25 wt% aluminium, suitably from 7 to 13 wt% chromium and from 18 to 23 wt% aluminium, suitably from 8 to 12 wt% chromium and from 20 to 22 wt% aluminium. Suitably the upper coating layer of the intermediate region is a nickel alloy comprising approximately 10 wt% chromium and approximately 21 wt% aluminium. Suitably the upper coating layer of the intermediate region is a nickel alloy comprising 10 wt% chromium and 21 wt% aluminium.

[0046] Suitably the upper coating layer of the intermediate region comprises nickel, chromium and aluminium, with chromium and aluminium being present in the above amounts and nickel providing the remaining wt% of the upper coating layer of the intermediate region.

[0047] Suitably the upper coating layer of the intermediate region consists essentially of nickel, chromium and aluminium, with chromium and aluminium being present in the above amounts and nickel providing the remaining wt% of the upper coating layer of the intermediate region.

[0048] The intermediate region may comprise an interlayer between the upper coating layer and the MCrAlX layer. The interlayer may provide a diffusion barrier to limit the loss of aluminium from the upper coating layer by diffusion to the MCrAlX layer which may otherwise have a detrimental effect on the performance of the upper coating layer by reducing the amount of aluminium present which forms protective alumina scales. Also, the interlayer may provide a diffusion barrier to limit the diffusion of metallic elements from the substrate to the upper coating layer, which may otherwise have a detrimental effect on the performance of the upper coating layer.

[0049] Suitably the interlayer is a nickel alloy comprising from 30 to 40 wt% chromium and from 35 to 45 wt% aluminium, suitably from 32 to 38 wt% chromium and from 37 to 43 wt% aluminium, suitably from 34 to 36 wt% chromium and from 39 to 41 wt% aluminium. Suitably the interlayer is a nickel alloy comprising approximately

35 wt% chromium and approximately 40 wt% aluminium. Suitably the interlayer is a nickel alloy comprising 35 wt% chromium and 40 wt% aluminium.

[0050] Suitably the interlayer comprises nickel, chromium and aluminium, with the chromium and aluminium being present in the above amounts and nickel providing the remaining wt% of the interlayer.

[0051] Suitably the interlayer consists essentially of nickel, chromium and aluminium, with the chromium and aluminium being present in the above amounts and nickel providing the remaining wt% of the interlayer.

[0052] Suitably the component is a turbine aerofoil comprising a tip, a platform and a root; wherein the first region of the component is a top region of the turbine aerofoil comprising the tip; and wherein the second region of the component is a bottom region of the turbine aerofoil between the platform and the root.

[0053] In said embodiments, the component suitably comprises the intermediate region and this intermediate region is a region of the turbine aerofoil which is between the top region of the turbine aerofoil and the platform.

[0054] As mentioned above, the top region of a turbine aerofoil is exposed to temperatures of between 800-950 °C or greater in use and therefore may undergo Type I hot corrosion. The top region of the aerofoil (the first region) having the aluminium-rich region as the upper coating layer described above may provide improved resistance to such Type I hot corrosion compared to a similar component either having no coating, an upper coating layer of MCrAlX composition or an upper coating of a chromium-rich layer as described above.

[0055] As mentioned above, the bottom region of a turbine aerofoil is exposed to temperatures of between 600-650 °C in use and therefore may undergo Type II hot corrosion. The bottom region of the aerofoil (the second region) having the chromium-rich region as the upper coating layer described above may provide improved resistance to such Type II hot corrosion compared to a similar component having either no coating, an upper coating layer of MCrAlX composition or an upper coating of an aluminium-rich region as described above.

[0056] The intermediate region of a turbine aerofoil is exposed to temperatures of between 700-900 °C in use and therefore may undergo Type I or Type II hot corrosion to a lesser extent than the top region and bottom region respectively. The intermediate region of the aerofoil having the upper coating described above may provide improved resistance to either type of hot corrosion experienced at these temperatures compared to a similar component having either no coating or an upper coating layer of MCrAlX composition.

[0057] Suitably the different upper coating compositions in different regions of the component, for example the first and second regions, are mixed with the adjacent region at an interface region.

[0058] The inventors have found that such a mixing of adjacent upper coating layers at different regions of the coating provides a more gradual change in composition

and properties from one region to the adjacent region than would otherwise be possible. This may also provide a stronger bond between adjacent regions than if the coating had a step change in upper coating composition between regions.

[0059] Suitably the upper coating layer has a composition gradient across at least one dimension of the component, between the first region and the second region.

[0060] A composition gradient is typically considered to be a variance in composition across a component, for example the composition of the upper coating layer may vary in at least chromium and aluminium along the component.

[0061] Suitably the composition gradient is a gradual change in composition from the first region to the second region of the component. Such a composition gradient may be distinct from a step change in composition between different regions in components.

The MCrAlX layer

[0062] In some embodiments, the MCrAlX layer has the same composition throughout the component, for example throughout the first, second and intermediate regions, when present.

[0063] Alternatively, the MCrAlX layer may have a different composition in the first region compared to the second region. The MCrAlX layer of the first region may have improved resistance to the higher temperature Type I hot corrosion processes discussed above, relative to the second region. The MCrAlX layer of the second region may have improved resistance to the lower temperature Type II hot corrosion processes discussed above, relative to the first region.

[0064] Suitably in the first region, M = Ni or Ni and Co in the MCrAlX layer. Suitably, the MCrAlX layer of the first region is an NiCrAlX layer or a NiCoAlX layer. The inventors have found that such NiCrAlX and NiCoAlX layers may provide better resistance to Type I hot corrosion processes than other MCrAlX coatings.

[0065] Suitably in the second region, M = Co in the MCrAlX layer. Suitably, the MCrAlX layer of the first region is a CoCrAlX layer. The inventors have found that such CoCrAlX layers may provide better resistance to Type II hot corrosion processes.

[0066] The MCrAlX layer of the first region may comprise tantalum, suitably from 0.05 to 0.5 wt% tantalum, suitably from 0.05 to 0.2 wt% tantalum. Tantalum may improve the oxidation resistance of the MCrAlX layer in the first region of the component, in particular at a turbine aerofoil tip, than other MCrAlX coatings.

[0067] The MCrAlX layer of the first region may comprise from 0.01 to 5 wt% silicon, suitably from 1 to 4 wt% silicon, suitably from 2 to 3 wt% silicon, suitably approximately 2.5 wt% silicon, suitably 2.5 wt% silicon. Such amounts of silicon in the MCrAlX layer of the first region may improve cyclic oxidation resistance, in particular at temperatures of up to 1000 °C experienced by a turbine

aerofoil tip, in use. Suitably in the intermediate region, when present, the MCrAlX layer has a composition which is between the composition of the MCrAlX layer in the first region and the composition of the MCrAlX layer in the second region.

[0068] Suitably the MCrAlX layer has a composition gradient across at least one dimension of the component, between the first region and the second region and across the intermediate region, when present.

[0069] Suitably the MCrAlX coating layer, whether in the first, second, intermediate or other regions of the component, comprises one or more of rhodium, yttrium, hafnium and zirconium. Suitably the MCrAlX coating layer comprises at least one of yttrium, hafnium or zirconium. For example, the MCrAlX coating layer may comprise yttrium and zirconium.

[0070] In said embodiments, the MCrAlX coating layer may comprise from 0.01 to 5wt% yttrium, hafnium or zirconium, suitably from 0.1 to 3 wt% yttrium, hafnium or zirconium, suitably from 0.5 to 2 wt% yttrium, hafnium or zirconium. Suitably the MCrAlX coating layer comprises yttrium in the above amounts. Suitably the MCrAlX coating layer comprises yttrium and zirconium in the above amounts.

[0071] A relatively small amount of yttrium in the MCrAlX coating layer can improve alumina scale adhesion to the coating. Yttrium can perform this function by combining with sulphur and prevent its segregation to the oxide layer, which is detrimental to the alumina scale adhesion. Relatively small amounts of hafnium can perform a similar function.

[0072] Suitably the thickness of the MCrAlX layer and the upper coating layer combined on the component is from 10 to 30 µm.

Method of coating

[0073] According to a second aspect of the present invention, there is provided a method of coating a component, the method comprising the steps of:

- a) cold spraying a first coating composition onto a first region of the component;
- b) cold spraying a second coating composition onto a second region of the component;

wherein steps a) and b) are carried out in a single coating operation.

[0074] Suitably the method of this second aspect provides a component according to the first aspect. The component, first region and second region referred to in relation to this second aspect may have any of the features or advantages of the component, first region and second region referred to in relation to the first aspect. Therefore the first coating composition and the second coating composition may have the composition described in relation to the upper coating layer in the first and second regions of the component of the first aspect, respectively. There-

fore the first coating composition may have the composition referred to in relation to the aluminium-rich region of the first aspect and the second coating composition may have the composition referred to in relation to the chromium-rich region of the first aspect.

[0075] Steps a) and b) are carried out in a single coating operation. Suitably a single coating operation is when the coating method is uninterrupted by, for example, changing coating compositions, changing coating apparatus, masking off a region of the component, removing a masking from a region of the component or removing the component from the coating apparatus.

[0076] Suitably steps a) and b) are carried out by a single cold spray apparatus.

[0077] Suitably steps a) and b) are carried out simultaneously. Suitably steps a) and b) are carried out simultaneously by a single cold spray apparatus.

[0078] The inventors have found that the method of this second aspect can be carried out without masking off different parts of the component being coated. Suitably the method of this second aspect does not comprise a masking off step. Suitably the method does not comprise a masking off step between step a) and step b). Avoiding such masking off steps can provide a much more efficient coating process and so improve the efficiency of the component manufacture.

[0079] Suitably the method of this second aspect involves mixing powders from at least two powder storage vessels to provide the first coating composition and/or the second coating composition.

[0080] In some embodiments, the method of this second aspect involves cold spraying further coating compositions onto further regions of the component. For example, the method may involve coating an intermediate region with a third coating composition. Such an intermediate region may have any of the features and advantages referred to in relation to the intermediate region of the first aspect.

[0081] Suitably the coating of the component, including steps a) and b), is carried out according to a computer model of the component. Suitably a computer model of the component is generated before the method of coating is carried out. The computer model may contain information regarding what coating composition is to be applied to which region of the component, according to what chemical and/or mechanical properties have been determined to be necessary for each region.

[0082] According to a third aspect of the present invention, there is provided an apparatus for coating a component, the apparatus comprising:

at least one cold spray unit;

a carrier gas supply arranged in communication with the at least one cold spray unit;

at least two powder storage vessels each arranged in communication with the at least one cold spray

unit; and

a control unit;

5 wherein the at least two powder storage vessels are each provided with a metering device for controlling flow of powder from the powder storage vessels to the at least one cold spray unit; and

10 wherein the control unit is adapted to control the metering devices and the at least one spray unit.

[0083] The apparatus of this third aspect may be adapted to carry out a method of the second aspect and/or to provide a component according to the first aspect.

15 **[0084]** A suitable cold spray unit comprises a convergent-divergent nozzle for directing powder compositions, accelerated by said carrier gas, to a surface of a component to be coated (a target substrate). The apparatus suitably comprises more than one cold spray unit. For example, in some embodiments the apparatus comprises two cold spray units. In some embodiments, the apparatus comprises more than two cold spray units. For example, in some embodiments the apparatus comprises three cold spray units.

[0085] Suitably the apparatus of this third aspect is adapted to combine powders from the at least two powder storage vessels to form a powder coating composition for coating onto a component.

30 **[0086]** In some embodiments, the at least two powder storage vessels are each arranged in communication with the different cold spray units (of the "at least one cold spray unit" of the apparatus). Therefore in such embodiments, the apparatus comprises at least two cold spray units which are each arranged in communication with different powder storage vessels (of the "at least two powder storage vessels" of the apparatus). By "arranged in communication with" we mean that the stated parts of the apparatus are able to have powder transferred between them.

35 **[0087]** During use of said embodiments of the apparatus, the at least two powder storage vessels may each be provided with a different powder coating composition which may then be coated onto different regions of said component by the different at least two cold spray units. Therefore a component can be provided with a coating having a different composition in different regions of said component. For example, a first region of said component may be provided with a first coating composition from a first powder storage vessel through a first cold spray unit; and a second region of said component may be provided with a second coating composition from a second powder storage vessel through a second cold spray unit. The first and second regions and first and second coating compositions may have any of the suitable features and advantages described in relation to the first and second aspects.

[0088] In some embodiments, the at least two powder

storage vessels are each arranged in communication with the same cold spray unit (of the "at least one cold spray unit" of the apparatus). Therefore in such embodiments, the apparatus comprises at least one cold spray unit which is arranged in communication with the at least two powder storage vessels.

[0089] During use of said embodiments of the apparatus, the at least two powder storage vessels may each be provided with a different powder coating composition ingredient which are then mixed according to the operation of the metering devices of the at least two powder storage vessels to provide a powder coating composition which may then be coated onto a region of said component by the cold spray unit. The cold spray unit may then be moved relative to the component and the metering devices operate to mix said coating composition ingredients in the at least two storage vessels to provide a different powder coating composition which is then coated onto a different region of said component. Therefore a component can be provided with a coating having a different composition in different regions of said component, using a single cold spray unit. For example, a first region of said component may be provided with a first coating composition through the cold spray unit; and a second region of said component may be provided with a second coating composition through the same cold spray unit. The first and second regions and first and second coating compositions may have any of the suitable features and advantages described in relation to the first and second aspects.

[0090] The apparatus may comprise a plurality of cold spray units each arranged in communication with a plurality of powder storage vessels and the metering devices may function to provide powders from any of the powder storage vessels to any of the cold spray units, in order to provide the appropriate coating material to the appropriate region of the component.

[0091] Suitably the control unit is programmable with a computer model of said component and the control unit is adapted to activate the apparatus to provide particular coating compositions onto particular regions of said component according to said computer model.

[0092] Using the apparatus of this third aspect can therefore provide a component with a coating which is designed to provide specific chemical and mechanical properties at specific regions of the component. The apparatus can provide such a coating in a single continuous operation by the appropriate activation of the metering devices to provide the required components of the coating composition to the cold spray unit(s) as the cold spray unit(s) move over said component and coat different regions of said component. The apparatus of this third aspect can perform such a coating operation without masking off different parts of the component being coated. Avoiding such masking off steps can provide a much more efficient coating process and so improve the efficiency of the component manufacture.

Brief Description of the Drawings

[0093] Examples of the present disclosure will now be described with reference to the accompanying drawings, in which:

Figure 1 is a schematic of a first region of a component according to the first aspect of the present invention, having a coating;

Figure 2 is a schematic of a second region of a component according to the first aspect of the present invention, having a coating;

Figure 3 is a schematic of an intermediate region of a component according to the first aspect of the present invention, having a coating;

Figure 4 is a perspective view of a component according to the first aspect of the present invention, having a coating; and

Figure 5 is a schematic of cold spray apparatus according to the third aspect of the present invention being used to carry out a method according to the second aspect of the present invention.

Detailed Description

[0094] Figure 1 shows a schematic of the coating in a first region (110) of a component according to the first aspect of the present invention. The first region (110) comprises a substrate (111) of the component, an MCrAlY layer (112) and an upper coating layer which is an aluminium-rich region (113). The substrate is formed from a nickel alloy known in the art, for example a nickel alloy commonly used to construct turbine components such as turbine aerofoils, for example a nickel superalloy. The MCrAlY layer (112) is arranged between and in contact with the substrate (111) and the aluminium-rich region (113) and is therefore not exposed to the environment in use. The metal content of the MCrAlY layer (112) is as follows: 38.5 wt% cobalt, 32 wt% nickel, 21 wt% chromium, 8 wt% aluminium and 0.5 wt% yttrium.

[0095] The aluminium-rich region (113) is the outermost layer of the component in the first region which is exposed to the environment in use. The metal content of the aluminium-rich region (113) is as follows: 53 wt% nickel, 15 wt% chromium and 32 wt% aluminium. This aluminium-rich region (113) provides good resistance to Type I hot corrosion processes.

[0096] Alternatively, the metal content of the aluminium-rich region (113) may be as follows: 52.9 wt% nickel, 5 wt% chromium, 32 wt% aluminium, 10 wt% platinum and 0.1 wt% yttrium. This aluminium-rich region (113) provides good resistance to Type I hot corrosion processes.

[0097] Figure 2 shows a schematic of the coating in a

second region (120) of a component according to the first aspect of the present invention. The second region (120) comprises a substrate (121) of the component, an MCrAlY layer (122) and an upper coating layer which is a chromium-rich region (123). The substrate and the MCrAlY layer (122) have the composition and arrangement described in relation to the corresponding parts of the first region (110).

[0098] The chromium-rich region (123) is the outermost layer of the component in the second region which is exposed to the environment in use. The metal content of the chromium-rich region (123) is as follows: 20 wt% nickel, 60 wt% chromium and 20 wt% aluminium. This chromium-rich region (123) provides good resistance to Type II hot corrosion processes.

[0099] Figure 3 shows a schematic of the coating in an intermediate region (130) of a component according to the first aspect of the present invention. The intermediate region (130) comprises a substrate (131) of the component, an MCrAlY layer (132), an upper coating layer which is an aluminium-rich layer (133) and an interlayer (134).

[0100] The substrate (131) and the MCrAlY layer (132) have the composition and arrangement described in relation to the corresponding parts of the first region (110).

[0101] The aluminium-rich upper coating layer (133) is the outermost layer of the component which is exposed to the environment in use. The metal content of the upper coating layer (133) is as follows: 69 wt% nickel, 10 wt% chromium and 21 wt% aluminium. This aluminium-rich upper coating layer (133) provides good resistance to Type I hot corrosion processes. The amount of aluminium in the aluminium-rich upper coating layer (133) in the intermediate region (130) is lower than the amount of aluminium in the aluminium-rich upper coating layer (113) in the first region (110) because the intended operating temperature of the intermediate region is lower than that of the first region. Therefore the amount of aluminium required to resist Type I hot corrosion processes in the intermediate region is lower than required in the first region.

[0102] The interlayer (134) is arranged between and in contact with the MCrAlY layer (132) and the aluminium-rich region of the upper coating layer (133). The metal content of the interlayer (134) is as follows: 25 wt% nickel, 35 wt% chromium and 40 wt% aluminium. The amount of chromium in the interlayer (134) in the intermediate region (130) is lower than the amount of chromium in the chromium-rich region of the upper coating layer (123) in the second region (120) because the intended operating temperature of the intermediate region is higher than that of the second region. Therefore the amount of chromium required to resist Type II hot corrosion processes in the intermediate region is lower than required in the second region.

[0103] Figure 4 shows component (100) which is a turbine aerofoil formed of a substrate of nickel alloy and a coating. The component (100) comprises a first region (110), a second region (120), an intermediate region

(130), a platform (140) and a root (150), which are common parts of such turbine aerofoils with known functions. The first region (110) of the component (100) comprises an aerofoil tip (115) and extends approximately 10 mm from the tip along the aerofoil blade (135). This first region (110) has the coating structure shown in Figure 1, having an MCrAlY layer (112) and an aluminium-rich region of the upper coating layer (113). The operating temperatures experienced by the first region (110) of component (100) are in the region of 800-950 °C or greater which causes Type I hot corrosion of such nickel alloy components. The aluminium-rich region of the upper layer (113) provides good resistance against this type of hot corrosion which would otherwise result in damage to and potentially failure of the component (100) in use.

[0104] The second region (120) of the component (100) extends from beneath the platform (140) to the top of the root (150). This second region (120) has the coating structure shown in Figure 2, having an MCrAlY layer (122) and a chromium-rich region of the upper coating layer (123). The operating temperatures experienced by the second region (120) of component (100) are in the region of 600-650 °C which causes Type II hot corrosion of such nickel alloy components. The chromium-rich region (123) provides good resistance against this type of hot corrosion which would otherwise result in damage to and potentially failure of the component (100) in use.

[0105] This chromium-rich region of the upper coating layer (123) in the second region (120) may also have relatively high ductility at said operating temperatures which may prevent a ductile to brittle transition which may lead to failure of the coating. Suitably the chromium-rich region of the upper coating layer (123) in the second region (120) has a ductile brittle transition temperature (DBTT) which is relatively low, suitably lower than the operating temperature of the this second region (120), therefore lower than 600-650 °C. Due to the different operating temperatures experienced by the first region (110) and the second region (120), the chromium-rich region of the upper coating layer (123) in the second region (120) suitably has a lower ductile brittle transition temperature than the aluminium-rich region of the upper coating layer (113) in the first region (110).

[0106] The intermediate region (130) of the component (100) extends from the first region (110) to the platform (140) and comprises a main part of the aerofoil blade (135). This intermediate region (130) has the coating structure shown in Figure 3, having an MCrAlY layer (132), an aluminium-rich region of the upper coating layer (133) and an interlayer (134). The operating temperatures experienced by the intermediate region (130) of component (100) are in the region of 700-900 °C which may cause Type I or Type II hot corrosion of such nickel alloy components, to a certain extent. The combination of aluminium-rich region of the upper coating layer (133) and interlayer (134) provides good resistance against both types of hot corrosion which would otherwise result in damage to and potentially failure of the component

(100) in use.

Formation of the coating by cold spray

[0107] Component (100) can be coated with the coating structures described above in relation to the first, second and intermediate regions (110, 120 and 130) using methods known in the art, for example by masking off the second region of the component whilst the first region of the component is being provided with the aluminium-rich region of the upper coating layer. Masking off certain regions of the component adds cost and complexity to the coating process. Other known methods of coating the component, such as pack aluminide, chemical vapour deposition, high-velocity oxy-fuel and electron beam physical vapour deposition, may involve the use of high temperatures. Such high temperatures typically result in localized stresses in the component substrate material when the coating cools down, which may cause significant thermal distortion of the component.

[0108] However, component (100) may be coated using cold spraying which may have significant advantages over other known coating methods. The main components of a cold spray apparatus are well known in the state of the art and include a powder storage vessel which stores and supplies powder coating material, a carrier gas supply for accelerating the powder materials, a mixing chamber and a convergent-divergent nozzle. During use of such a cold spray apparatus, powder particles strike the target surface causing a plastic deformation of the powder particles which ultimately results in the particles forming a strong bond with the target surface.

[0109] The powder coating materials used for cold spraying typically have a particle size (diameter) of 5-80 μm . Using smaller particle sizes enables higher particle velocities to be attained. Smaller particle sizes are used if the powder coating material is relatively hard. The powder coating materials are accelerated to supersonic velocities using compressed gas which is normally selected from helium, nitrogen or another inert gas.

[0110] As the powder coating materials are not heated to high temperatures during the cold spraying process, oxidation and/or degradation of the powder coating materials does not occur. Also, as relatively low temperatures are used in cold spraying compared to other known coating methods, thermal distortion of the component substrate material is substantially reduced. Another significant advantage of using cold spraying is the formation of significant compressive residual stress in the component which has the added benefit of improved life and mechanical integrity of the component. Furthermore, coating by cold spraying does not require the masking off of regions of the component which are not intended to be coated with a particular coating composition due to the very small stand-off distances between the cold spray apparatus and the target substrate. The removal of the requirement for masking off may provide a more efficient coating process and also avoid geometrical discontinui-

ties between different coating regions of the component which may otherwise be produced by other known coating methods.

[0111] However, the cold spray methods of the prior art are not able to provide to a component, in a single coating step, a coating having a different composition in different regions of the component. The cold spray apparatus (200) of Figure 5 can overcome this drawback of the cold spray apparatus of the prior art.

[0112] Cold spray apparatus (200) comprises three cold spray units (211, 212 and 213), three powder storage vessels (221, 222 and 223) and a control unit (240). The three cold spray units (211, 212 and 213) are each arranged in communication with a carrier gas supply (214) for accelerating powder coating material from the powder storage vessels towards a target substrate (component (100)). The three cold spray units (211, 212 and 213) are each arranged in communication with each of the three powder storage vessels (221, 222 and 223) for transfer of powder coating material from the powder storage vessels (221, 222 and 223) to the cold spray units (211, 212 and 213).

[0113] The three powder storage vessels (221, 222 and 223) are each provided with a metering device (231, 232 and 233) for controlling flow of powder coating material from the powder storage vessels (221, 222 and 223) to the three cold spray units (211, 212 and 213).

[0114] The control unit (240) is adapted to control the operation of the metering devices (231, 232 and 233) and therefore control the flow of powder coating material from the powder storage vessels (221, 222 and 223) to the three cold spray units (211, 212 and 213). The control unit (240) is also adapted to control the operation of the three cold spray units (211, 212 and 213).

[0115] The control unit (240) is adapted to control the metering devices (231, 232 and 233) and the three cold spray units (211, 212 and 213) to carry out a method of coating a component (100) according to a computer model of the coating and the component (300) programmed into the control unit (240). The cold spray apparatus (200) can therefore provide component (100) with a coating having a different composition in different regions of the component, for example a first region (110), a second region (120) and an intermediate region (130) as described above in relation to Figures 1-4, in a single coating operation. This cold spray method and apparatus may therefore efficiently provide a coating with a composition tailored in specific regions of the component to resist the specific corrosion mechanisms and/or to improve the mechanical properties of the component in those regions, in order to improve the performance and prolong the useful life of the component.

[0116] The three powder storage vessels (221, 222 and 223) may each be provided with a single element or compound, suitably metallic elements, which form part of a coating composition when said elements or compounds are combined and applied to a component by the cold spray apparatus (200). In such embodiments, the

control unit determines the amount of each of said elements or compounds to combine to form a powder coating mixture, by appropriate activation of the metering devices (221, 222 and 223), to provide said powder coating mixture to the appropriate cold spray unit for cold spraying onto the appropriate region of the component (100). For example, one of the three powder storage vessels may be charged with nickel powder, one with chromium powder and one with aluminium powder. The nickel, chromium and aluminium powders may then be supplied from the separate powder storage vessels to the cold spray units in proportions appropriate to provide the aluminium-rich region of the upper coating layer (113) in the first region (110) of the component (100), a chromium-rich region of the upper coating layer (123) in the second region (120) of the component and an (intermediate) aluminium-rich region of the upper coating layer (133) in the intermediate region (130) of the component (100).

[0117] Alternatively the three powder storage vessels (221, 222 and 223) may each be provided with a powder coating mixture corresponding to a coating composition intended for a specific region of the component (100). For example, the powder coating mixtures may be pre-alloyed powder mixtures. In such embodiments, the control unit (240) determines, by appropriate activation of the metering devices (221, 222 and 223), which of said powder coating mixtures to provide to the appropriate cold spray unit for cold spraying onto the appropriate region of the component (100). For example, powder coating compositions corresponding to the aluminium-rich region of the upper coating layer (113), the chromium-rich region of the upper coating layer (123) and the (intermediate) aluminium-rich region of the upper coating layer (133) may be charged into separate powder storage vessels. These powder coating compositions can then be supplied from the separate powder storage vessels to the cold spray units to provide the aluminium-rich region of the upper coating layer (113) in the first region (110) of the component (100), a chromium-rich region of the upper coating layer (123) in the second region (120) of the component and an (intermediate) aluminium-rich region of the upper coating layer (133) in the intermediate region (130) of the component (100).

[0118] Alternatively, some of the three powder storage vessels (221, 222 and 223) may be provided with single elements or compounds, suitably metallic elements, which form part of a coating composition, and some may be provided with powder coating mixtures. In such embodiments, the control unit (240) again determines which powders to combine to form the required powder coating mixture and to provide said powder coating mixture to the appropriate cold spray unit for cold spraying onto the appropriate region of the component (100).

[0119] The cold spray apparatus (200) may contain more than three cold spray units and/or powder storage vessels to enable further options for combining or providing different powder coating ingredients or mixtures onto different regions of a component.

[0120] Component (100) may be formed by coating the substrate (uncoated base alloy) in stages. Firstly the substrate of the component (100) may be coated with the MCrAlY by cold spraying. Secondly the MCrAlY layer may then be coated with the upper coating layers (and optionally interlayers) as described above in relation to Figures 1-4 by cold spraying using the cold spray apparatus (200). This allows the formation of the aluminium-rich region of the upper coating layer in the first region of the component, the chromium-rich region of the upper coating layer in the second region of the component and the specified layers in the intermediate region of the component, using a single coating operation. This coating method involves charging the appropriate powder elements or powder coating mixtures in the powder storage vessels (221, 222 and 223), as discussed above.

[0121] When other metals such as platinum and yttrium are required in the upper coating layer, these may be provided by either separate plating operations or may be included in one or more of the powder storage vessels, for example in a powder coating mixture with other metallic elements (pre-alloyed powders).

[0122] In summary, the present invention provides a component, such as a turbine aerofoil, comprising an anti-corrosion coating. The component comprises a substrate coated with an MCrAlY layer and an upper coating layer. The upper coating layer has an aluminium-rich zone in a first region of the component, for example in a top region of a turbine aerofoil comprising a tip of the turbine aerofoil. The upper coating layer has a chromium-rich zone in a second region of the component, for example in a bottom region of a turbine aerofoil between a platform and a root of the aerofoil. These specific upper coating layers may provide resistance to Type I hot corrosion in the first region of the component and resistance to Type II hot corrosion in the second region. The present invention also provides method of forming such a coating on a component and a cold spraying apparatus for applying such a coating.

[0123] Throughout this specification, the term "comprising" or "comprises" means including the component(s) specified but not to the exclusion of the presence of other components. The term "consisting essentially of" or "consists essentially of" means including the components specified but excluding other components except for materials present as impurities, unavoidable materials present as a result of processes used to provide the components, and components added for a purpose other than achieving the technical effect of the invention. Typically, when referring to compositions, a composition consisting essentially of a set of components will comprise less than 5% by weight, typically less than 3% by weight, more typically less than 1% by weight of non-specified components.

[0124] The term "consisting of" or "consists of" means including the components specified but excluding addition of other components.

[0125] Whenever appropriate, depending upon the

context, the use of the term "comprises" or "comprising" may also be taken to encompass or include the meaning "consists essentially of" or "consisting essentially of", and may also be taken to include the meaning "consists of" or "consisting of".

[0126] For the avoidance of doubt, wherein amounts of components in a composition are described in wt%, this means the weight percentage of the specified component in relation to the whole composition referred to. For example, "the aluminium-rich layer comprises 32 wt% aluminium" means that 32 wt% of the aluminium-rich layer is provided by aluminium.

[0127] Attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

[0128] All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

[0129] Each feature disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

[0130] The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

Claims

1. A component comprising a substrate, an MCrAlX layer on the substrate and an upper coating layer on the MCrAlX layer; wherein:

in a first region of the component, the upper coating layer is an aluminium-rich region of the upper coating layer; and

in a second region of the component, the upper coating layer is a chromium-rich region of the upper coating layer.

2. The component according to claim 1 comprising an intermediate region wherein the upper coating layer of the intermediate region has an aluminium content lower than the aluminium-rich region and higher than the chromium-rich region; and has a chromium con-

tent higher than the aluminium-rich region and lower than the chromium-rich region.

3. The component according to claim 1 or claim 2, wherein the intermediate region is located in the component between the first region and the second region.

4. The component according to any one of the preceding claims, wherein the substrate is a nickel alloy.

5. The component according to any one of the preceding claims, wherein the MCrAlX layer and the upper coating layer are nickel alloys.

6. The component according to any one of the preceding claims, wherein the aluminium-rich region of the upper coating layer is a nickel alloy comprising from 10 to 20 wt% chromium and from 20 to 40 wt% aluminium.

7. The component according to any one of the preceding claims, wherein the chromium-rich region of the upper coating layer is a nickel alloy comprising from 50 to 60 wt% chromium and from 15 to 20 wt% aluminium.

8. The component according to any one of the preceding claims, wherein the component is a turbine aerofoil comprising a tip, a platform and a root; wherein the first region of the component is a top region of the turbine aerofoil comprising the tip; and wherein the second region of the component is a bottom region of the turbine aerofoil between the platform and the root.

9. The component according to any one of the preceding claims, wherein the upper coating layer has a composition gradient across at least one dimension of the component, between the first region and the second region.

10. A method of coating a component, the method comprising the steps of:

a) cold spraying a first coating composition onto a first region of the component;

b) cold spraying a second coating composition onto a second region of the component;

wherein steps a) and b) are carried out in a single coating operation.

11. The method according to claim 10, wherein steps a) and b) are carried out by a single cold spray apparatus.

12. The method according to claim 10 or claim 11,

wherein steps a) and b) are carried out simultaneously.

13. The method according to any one of claims 9 to 12, wherein the coating of the component, including steps a) and b), is carried out according to a computer model of the component. 5

14. An apparatus for coating a component, the apparatus comprising: 10

at least one cold spray unit;
a carrier gas supply arranged in communication with the at least one cold spray unit;
at least two powder storage vessels each arranged in communication with the at least one cold spray unit; and 15
a control unit;
wherein the at least two powder storage vessels are each provided with a metering device for controlling flow of powder from the powder storage vessels to the at least one cold spray unit; 20
and
wherein the control unit is adapted to control the metering devices and the at least one spray unit. 25

15. The cold spray unit according to claim 14, wherein the control unit is programmable with a computer model of said component and wherein the control unit is adapted to activate the apparatus to provide particular coating compositions onto particular regions of said component according to said computer model. 30

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FIG 1

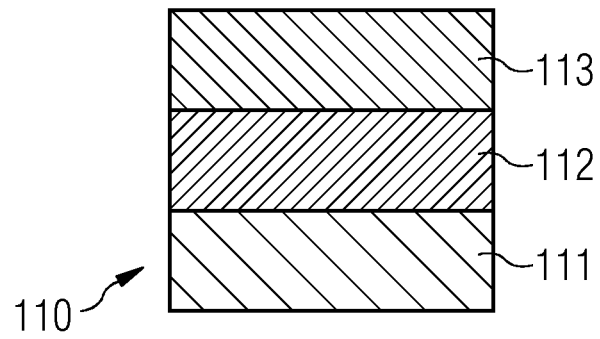


FIG 2

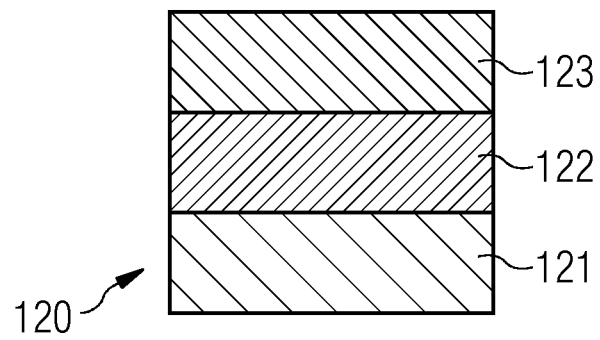


FIG 3

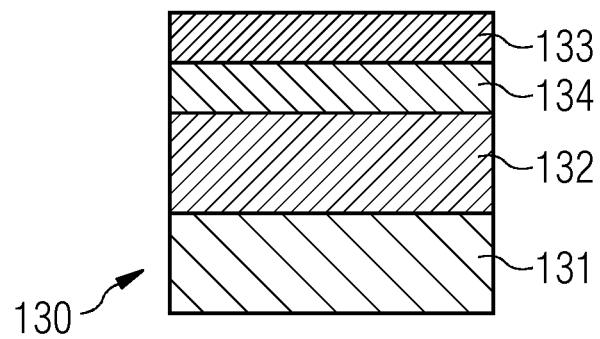


FIG 4

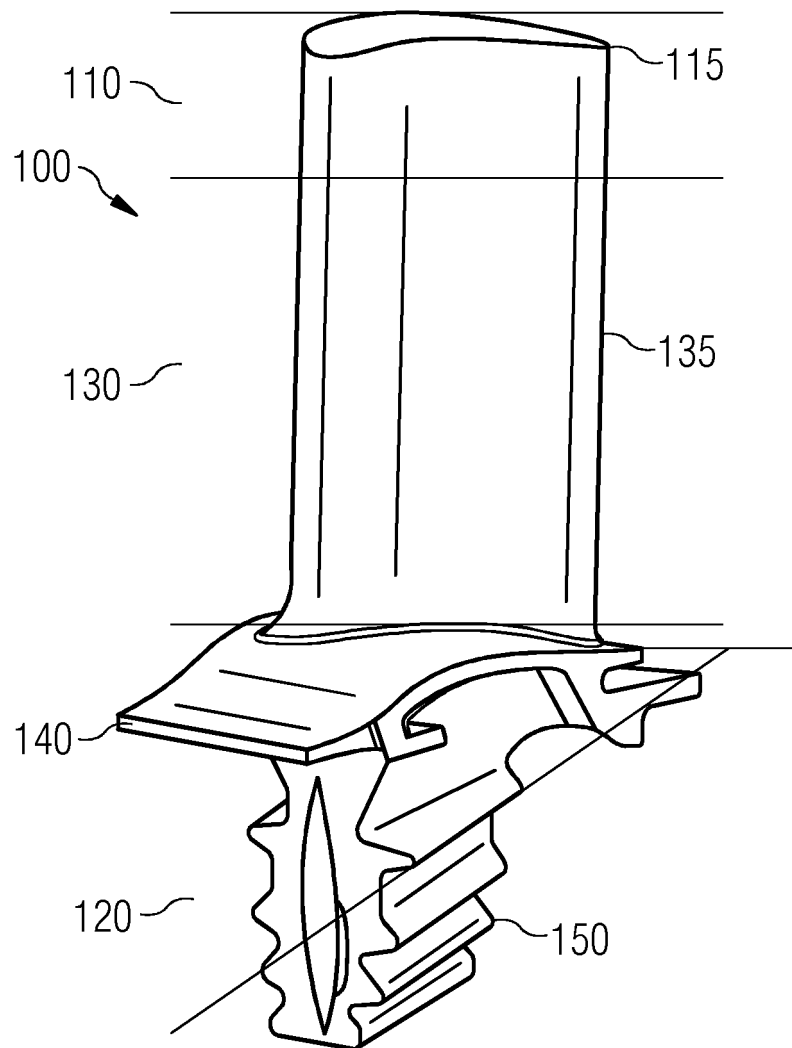
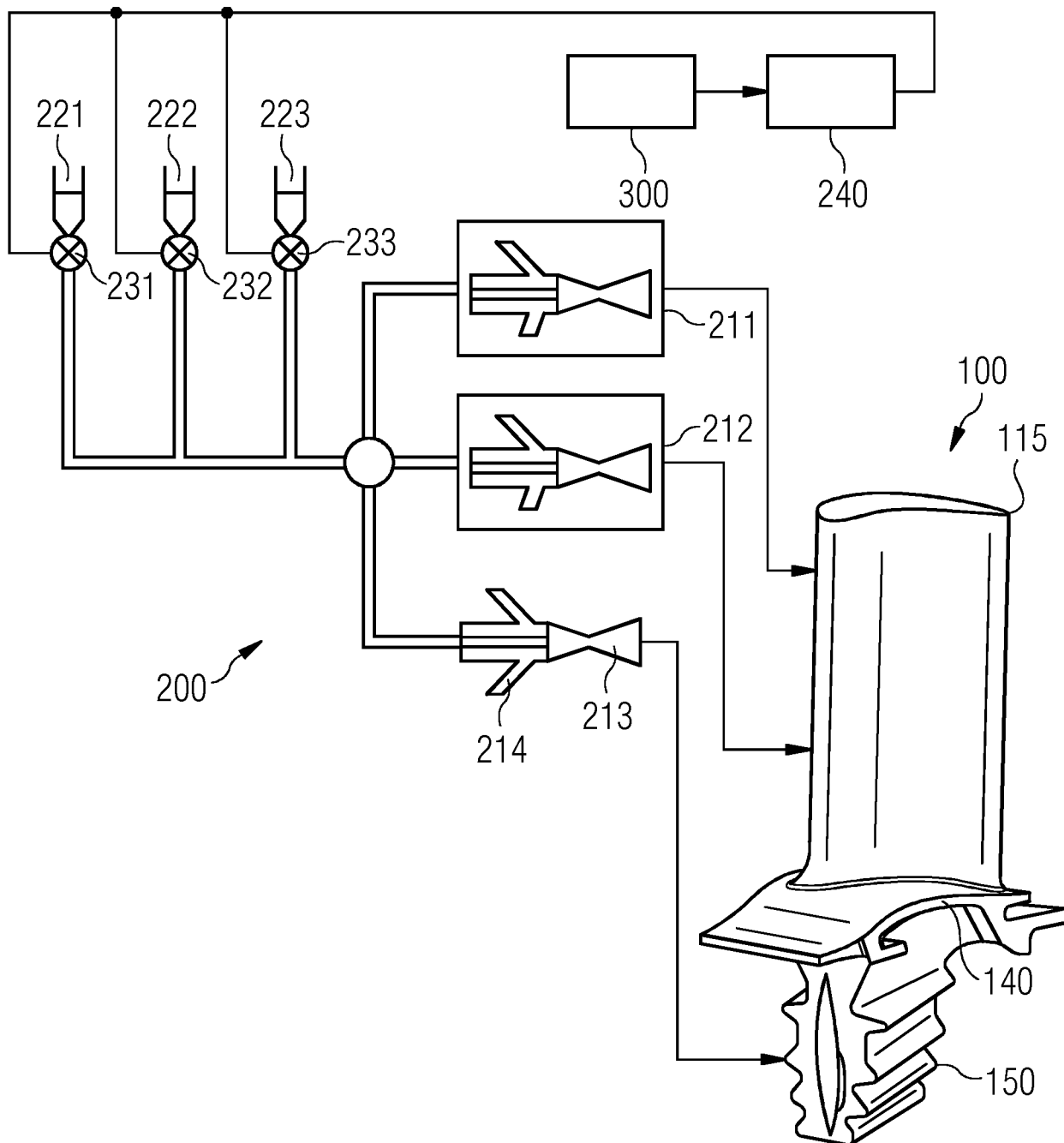


FIG 5





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