Engine Component and Associated Methods

The invention relates to an engine component for an engine with a combustion zone at a temperature of at least 1600 °C. The invention further relates to methods of applying a coating on a superalloy engine component.

The efficiency of engines, in particular gas turbine engines such as that used in aircraft engines, is improved when the temperature is as high as possible. This may particualrly apply to the combustion zone, where air and fuel are mixed and combusted, of a gas turbine engine, parts of pumps used in rocket engines or other engine components that are to be used at very high temperatures, such as the lining of the exhaust section of a gas turbine engine.

Such engine components therefore needs to be constructed from materials able to withstand these high temperatures. Engine components used in the combustion zone of modern gas turbines are typically made from superalloys (a well-known class of cobalt and nickel alloys specially adapted for use at high temperatures). Modern gas turbines are designed to operate with a combustion zone having a temperature of at least 1600°C, which is above the melting point of superalloys. It is therefore necessary to protect the superalloy against such high temperatures.

To protect the superalloy engine component a coating with a ceramic oxide is typically applied. The term ceramic oxide is used by different turbine manufacturers to refer to different groups of materials. In the present application the term refers to metal oxides that melt at a temperature higher than 1600°C.

The coefficients of thermal expansion of superalloys and ceramic oxides can differ significantly. Therefore when a coated superalloy engine component is heated the superalloy expands by a different amount than the coating.
This leads to stress at the interface between the superalloy and the coating, and eventually parts of the coating will fall off. The component then needs to be replaced. One known solution to this problem is to use an adhesion layer containing nickel and/or cobalt and 10-50 wt.% aluminium between the ceramic oxide and the superalloy. A coated engine component with a coating improved in this manner is shown in document D1.

The lifetime of the components of document D1 is improved, but can still be insufficient. Additionally, the adhesion layer increases the weight of the engine component, which is particularly disadvantageous if the component is to be used in aircraft engines.

Therefore, it is desirable to further improve the lifetime of superalloy engine components with ceramic oxide coatings or to reduce the weight of such components.

An engine component which solves these problems is provided by claim 1.

By providing a ceramic oxide layer having a columnar structure having columns with a space between adjacent columns, the coating can deform when the substrate and the ceramic oxide expand upon heating and much less stress at the interface between the superalloy and the coating is generated. As such, the coating is less likely to fall off. The columns must be orientated substantially perpendicularly to the surface to provide this effect. A column is considered to be substantially perpendicular if the angle between the column and the surface of the substrate is between 75 and 105°.

The coating with a columnar structure can be used with the adhesion layer of D1. In this case the lifetime of the engine component will be significantly increased compared to the arrangement of D1.

Alterantively, the adhesion layer can be omitted and the ceramic oxide deposited directly on the substrate. Such a component will have a lifetime similar to the components known from document D1 but will weigh less.

It has been found that protection of superalloys against high temperatures is just as good with the ceramic oxide layer having a columnar microstructure as with conventional ceramic oxide layers.

Optional and preferable features of the engine component are provided by claims 2 to 7.

To form ceramic oxide coatings on engine components, electron-beam evaporation can be used. Such a technique is already known from D2 for coating superalloy turbine blades with ceramic oxide (e.g. zirconium oxide) in a columnar microstructure. However, the coating applied by the technique is very thin since it is used for security purposes only and may be removed, and therefore is insufficient for high temperature application, i.e. above at least 1600 °C. As such, components formed by the technique of D2 would not be suitable for modern gas turbines.

Therefore, it is desirable to provide a method of coating a superalloy engine component with a cearmic oxide coating which is sufficient for high temperature application, i.e. above at least 1600 °C.

A method of depositing a coating which solves this problem is provided by claim 8.

Since the coating has a thickness of at least 25 micrometres, thermal insulation is sufficient to allow operation of the component at temperatures above 1600 °C.

Optional and preferable features of the method are provided by claims 9 and 10.

Alternatively, a ceramic oxide coating can be applied to engine components by other more conventional means, such as plasma spraying. D1 describes such a process. However, the process of D1 does not result in a columnar microstructure. As such, the lifetime of the component formed by the method of document D1 is improved as compared to coatings without adhesion layers, but can still be insufficient. Additionally, the adhesion layer is necessary to improve the lifetime which increases the weight of the engine component, which is particularly disadvantageous if the component is to be used in aircraft engines.

Therefore, it is desirable to provide a method of applying a ceramic oxide coating whihc further improves the lifetime of superalloy engine components with ceramic oxide coatings or to reduce the weight of such components.

A method of applying a coating which solves these problems is provided by claim 11.

The machining provides a columnar structure which provides the same advantages over D1 as indicated previously.

Optional and preferable features of the method are provided by claims 12 to 15.

In an adjacent technical field, an engine component from a hot part of a bus engine is known which consists of aluminium coated with a 30 micrometer ceramic oxide having a columnar microstructure with columns perpendicular to the surface of the engine component. The ceramic oxide having a columnar microstructure was made by anodisation. However, such a component would be unsuitable for use in an engine with a combustion zone at a temperature of at least 1600 °C, since it is formed from aluminium (rather than a superalloy) which would not withstand the required temperature, even when coated. The anodisation technique cannot be used on superalloy.

Claims

1. An engine component (10; 20) for an engine with a combustion zone at a temperature of at least 1600 °C, the engine component (10; 20) comprising:

a superalloy substrate (11; 21); and

a coating on the superalloy substrate (11; 21), the coating having a ceramic oxide layer (12; 22) of a thickness of at least 25 micrometres, the ceramic oxide of the ceramic oxide layer (12; 22) being a metal oxide that melts at a temperature higher than 1600 °C;

characterised in that the ceramic oxide layer (12; 22) has a columnar structure having columns (14a, 14b, 14c; 24a, 24b, 24c) with a space (15a, 15b; 25) between adjacent columns (14a, 14b, 14c; 24a, 24b, 24c), an angle between each column (14a, 14b, 14c; 24a, 24b, 24c) and a surface of the superalloy substrate (11; 21) being betwen 75 and 105°.

2. An engine component (10; 20) as claimed in claim 1, wherein the coating has an adhesion layer between the superalloy substrate (11; 21) and the ceramic oxide layer (12; 22), the adhesion layer containing nickel and/or cobalt and 10-50 wt.% aluminium.

3. An engine component (10; 20) as claimed in claim 2, wherein the adhesion layer has a thickness of 10-200 micrometres.

4. An engine component (10; 20) as claimed in any one of the preceding claims, wherein the ceramic oxide layer (12; 22) has a thickness which does not exceed 2 millimetres.

5. An engine component (10; 20) as claimed in any one of the preceding claims, wherein a type of ceramic oxide of the ceramic oxide layer (12; 22) is selected from a class of: zirconium oxide, aluminium oxide, titanium oxide, and complex oxides with a pyrochlore structure.

6. An engine component (10; 20) as claimed in any one of the preceding claims, wherein the engine component (10; 20) is a turbine component.

7. An engine component (10; 20) as claimed in claim 6, wherein the turbine component is a turbine blade (31), the turbine blade (31) having a hollow centre and walls, holes (31a, 31b, 31c) being provided from the hollow centre and through the walls and coating for passing cooling air from the hollow centre to an exterior surface of the turbine blade (31).

8. A method of depositing a coating on an engine component (10) comprising a superalloy substrate (11) for an engine with a combustion zone at a temperature of at least 1600 °C, the method comprising the steps of:

placing the engine component (10) and a ceramic oxide source in a vacuum chamber, the ceramic oxide of the ceramic oxide source being a metal oxide that melts at a temperature higher than 1600 °C;

evacuating the vacuum chamber;

heating the engine component (10) to a temperature of 920-1050 °C and evaporating the ceramic oxide source with an electron beam so that a coating having a ceramic oxide layer (12) is deposited on the superalloy substrate (11) of the engine component (10), the cearmic oxide layer having a columnar structure having columns (14a, 14b, 14c) with a space (15a, 15b) between adjacent columns (14a, 14b, 14c), an angle between each column (14a, 14b, 14c) and a surface of the substrate (11) being between 75 and 105°, the ceramic oxide of the ceramic oxide layer (12) being a metal oxide that melts at a temperature higher than 1600 °C;

characterised in that the ceramic oxide layer (12) has a thickness of at least 25 micrometres.

9. A method as claimed in claim 8, wherein an adhesion layer source containing nickel and/or cobalt and 10-50 wt.% aluminium is placed in the vacuum chamber with the engine component (10) and a ceramic oxide source, and theadhesion layer source is evaporated with the electron beam so that an adhesion layer containing nickel and/or cobalt and 10-50 wt.% aluminium is deposited on the superalloy substrate (11) of the engine component (10) before the engine component (10) is heated to between 920-1050 °C and before evaporating the cearmic oxide source.

10. A method as claimed in claim 8 or claim 9, wherein the ceramic oxide source and ceramic oxide layer (22) is zirconium oxide and the engine component (10) is heated to a temperature of 950-1000°C.

11. A method of applying a coating on an engine component (20) comprising a superalloy substrate (21) for an engine with a combustion zone at a temperature of at least 1600 °C, the method comprising the steps of:

applying a coating having a ceramic oxide layer (22) to the superalloy substrate (21) of the engine component (20), the ceramic oxide layer (22) of a thickness of at least 25 micrometres, the ceramic oxide of the ceramic oxide layer (22) being a metal oxide that melts at a temperature higher than 1600 °C;

characterised by machining the coating to form a columnar structure in the ceramic oxide layer (22), the columnar structure having columns (24a, 24b, 24c) with a space (25) between adjacent columns (24a, 24b, 24c), an angle between each column (24a, 24b, 24c) and a surface of the superalloy substrate (21) being between 75 and 105°.

12. A method as claimed in claim 11, wherein an adhesion layer containing nickel and/or cobalt and 10-50 wt.% aluminium is applied before the ceramic oxide layer (22).

13. A method as claimed in claim 11 or claim 12, wherein the coating is applied via plasma spraying.

14. A method as claimed in any one of claims 11 to 13, wherein the machining is carried out by a laser.

15. A method as claimed in claim 14, wherein the engine component (20) is a turbine blade (31) having a hollow centre and walls, and the method further comprises drilling the coating and walls with the laser to form holes (31a, 31b, 31c) from the hollow centre and through the walls and

coating for passing cooling air from the hollow centre to an exterior surface of the turbine blade (31).