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PROCESS OF FORMING ALUMINIDE COATINGS ON NICKEL AND COBALT BASE SUPERALLOYS

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ABSTRACT OF THE DISCLOSURE

The method of coating the superalloys wherein the substrate is first coated with a low melting eutectic-type alloy consisting predominantly of elements that form stable aluminides and subsequently aluminizing the coated substrate.

BACKGROUND OF THE INVENTION

The present invention relates in general to oxidation-resistant coatings for metals and, more particularly, to aluminide coatings for the nickel and cobalt-base superalloys.

There are a number of the nickel and cobalt-base superalloys that are widely utilized in various gas turbine engines, particularly in the hot section thereof. Included among these materials are those identified in the industry as follows:

Alloy:	Nominal composition (wt. percent)
Udimet 700:	
Cr	15
Co	18.5
Ti	3.25
Al	4.25
Mo	5
C	.1
B	.03
MAR M200:	
Cr	9
Co	10
Ti	2
Al	5
Cb	1
W	12.5
C	.15
B	.015
Zr	.05
Balance Ni	
B–1900:	
Cr	8
Co	10
Ti	1
Al	6
Mo	6
Ta	4.3
C	11
B	15
Zr	.07
Balance Ni	
WI 52:	
Cr	21
W	11
Fe	1.75
Cb+Ta	2
C	45
Balance Co	

While the superalloys are reasonably resistant to oxidation-erosion, in the more demanding applications, such as turbine blades and vanes and other hot section components, a coating is usually provided to improve the oxidation-erosion resistance of the alloy. Typical of the coating processes used are the pack coating method described by Wachtell et al. 3,257,230 and the slurry method of Joseph 3,102,044. These processes are utilized to form by reaction with one or more of the substrate elements, an aluminide or aluminides which display good oxidation-erosion resistance and, thus the operating lifetimes of the superalloy components are extended beyond those attainable with the uncoated alloys.

Because these coatings are dependent upon reaction with the substrate constituents, the basic protective coating achieved in each case varies because of differences in substrate composition which is, of course, reflected in the coating composition. Furthermore, because the protective function of the coating is dependent upon the substrate composition, it is possible to form aluminides which are not optimum in terms of their oxidation resistance or other properties or which perhaps contain certain less desirable elements as a result of coating-substrate interdiffusion.

SUMMARY OF THE INVENTION

The present invention contemplates a process for improving the characteristics of the aluminum-base protective coatings on the superalloys by first applying to the surface thereof, a low melting eutectic or eutectic-type alloy which consists predominantly of elements that form stable oxidation-resistant aluminides or impart other desirable characteristics to the coating. Subsequent processing involving a high temperature heat treatment usually associated with the formation of the aluminides, causes a degree of interdiffusion with the basis metal and raises the melting point of the system.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention basically involves conditioning of the surface of a superalloy substrate to condition it or enrich it in those elements which form a desirable coating particularly an aluminide coating. For this purpose a thin layer of a eutectic or eutectic type alloy is applied to the substrate prior to the aluminizing cycle. A layer of 0.005–0.008 inch, after aluminizing is preferred.

Representative eutectic compositions suitable for generating coatings for gas turbine engine applications are set forth in Table I.

TABLE I

Composition (wt. percent)	Melting point (° F.)
(1) Co—21 Cb	2250
(2) Ni—37 Ta	2480
(3) Ni—51.6 Cb	2150
(4) Co—32.4 Ta	2325
(5) Cr—48 Ni	2450
(6) 37 Cr—46 Ni—17 Ta	2185

Of the elements listed in the above compositions, all form stable, oxidation-resistant aluminides, with the exception of chromium, the chromium offering advantages in imparting sulfidation or hot corrosion resistance to the superalloys and superalloy coatings. While not inclusive of all favorable binary or ternary eutectic systems or eutectic-like systems, the representative compositions listed above offer considerable variety in selecting a particular coating system for a given application.

In selecting a given eutectic system for conditioning the superalloy substrate surface, prime consideration is given to those elements which form stable, oxidation-resistant aluminides. However, other factors also may merit consideration. The superalloys in some instances are adversely affected by exposure to certain critical temperatures. With the variety of eutectic systems available, it is therefore possible and sometimes essential to select the particular preconditioning alloy not so much in terms of its ability to form particular aluminides as by its temperature of application. Furthermore, the economics of a production process may dictate the advisability of selecting a eutectic having a melting point consonant with a heat treatment temperature utilized for the alloy involved. For example, the melting point of the Co—21 Cb eutectic at 2250° F. corresponds to a standard heat treatment temperature associated with directionally-solidified (columnar grain) MAR M 200 alloy turbine vanes. The melting point of the CO—32.4 Ta eutectic, on the other hand, at 2325° F. corresponds with the homogenization heat treatment temperature utilized with certain nickel-molybdenum-aluminum superalloys.

In applying the eutectic to the substrate, any of the conventional methods such as dipping, flame spraying, etc. are satisfactory, and the desired thickness is achieved. Typically, no diffusional heat treatment prior to the aluminizing step is required. Good adherence occurs as long as a uniform coating of the eutectic and complete wetting of the substrate is initially achieved.

Example 1

A TD (98% Ni, 2% Tho_2) nickel substrate was coated with the Ni—37 Ta eutectic by slurry to a thickness of 0.004 inch. The conditioned substrate was thereafter aluminized in a conventional pack cementation process to effect conversion of the eutectic components to the desired aluminides.

The results of testing of the coated specimen is summarized in Table II.

TABLE II

Test—Oxidation-erosion
Test temperature, F.—2200
Results—180 hours to failure.

Example 2

A MAR M–200 alloy sample was coated with the 37 Cr—46 Ni—17 Ta alloy to a thickness of 0.005 inch by plasma spraying and subsequently aluminized in a slurry process to form the protective aluminides.

The results of oxidation-erosion testing are summarized in Table III.

TABLE III

Test—Oxidation-erosion
Test temperature, F.—2100
Results—No failure at 380 hours. Test discontinued.

Example 3

A TD (98% Ni, 2% Tho_2) nickel sample was coated with the Cr—48 Ni alloy to a thickness of 0.005 inch and subsequently aluminized.

The test results with this combination are summarized in Table IV.

TABLE IV

Test—Hot corrosion (1 p.p.m. salt ingestion)
Test temperature, F.—1800
Results—No failure at 500 hours. Test discontinued.

The present invention, therefore, may be seen to include the step of precoating the superalloy substrate, prior to aluminizing, with an eutectic or eutectic-type alloy rich in those elements capable of subsequent transformation or conversion to elements resistant at high temperature to oxidation-erosion, such as the various metallic aluminides, and including on an optional basis, those other materials such as chromium, which impart other characteristics such as hot corrosion resistance to the coating. As used herein, the terms eutectic or eutectic-type, has reference to the low melting alloy compositions in a given alloy system, including not only the binary and ternary eutectic compositions, but also those compositions which display eutectic-type or quasi-eutectic behavior.

The advantages of preconditioning the superalloys with a suitable eutectic and thus providing at the substrate surface those components which form, upon subsequent processing, oxidation-resistant compounds, principally the aluminides, have been established. While the invention has been described in detail with reference to certain examples and preferred embodiments these are illustrative only. It will be understood that the invention is not limited to the exact details described, for obvious modifications will occur to those skilled in the art.

What is claimed is:

1. In the processes for generating a protective oxidation, resistant aluminide coating on the nickel-base and cobalt-base superalloys, the improvement which comprises:
prior to forming the protective aluminide coating;
precoating the superalloy substrate with a eutecic alloy consisting essentially of at least one element capable of forming a stable oxidation-resistant aluminide.

2. The improvement according to claim 1 in which: the eutectic alloy has a melting point in excess of 2000° F.

3. The improvement according to claim 1 in which: the eutectic alloy has a melting point of about 2000° F.–2600° F.

4. A process for generating a protective aluminide coating on the nickel and cobalt base superalloys which comprises:
precoating the superalloy substrate with a eutectic alloy the principal components of which are selected from the group consisting of nickel, cobalt, columbium, tantalum and chromium;
and aluminizing the precoated substrate to convert at least one of the eutectic alloy elements to an oxidation-resistant aluminide.

5. The process according to claim 4 in which the eutectic alloy is selected from the group of eutectic alloys consisting of, by weight:
nickel—37 percent tantalum;
nickel—51.6 percent columbium;
cobalt—21 percent chromium;
cobalt—32.4 percent tantalum;
chromium—48 percent nickel; and
37 percent chromium—46 percent nickel—17 percent tantalum.

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