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[54] **COMPOSITE COATING FOR THE SUPERALLOYS**

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[58] **Field of Search** 29/198, 194, 196.6; 75/171

[56] **References Cited**

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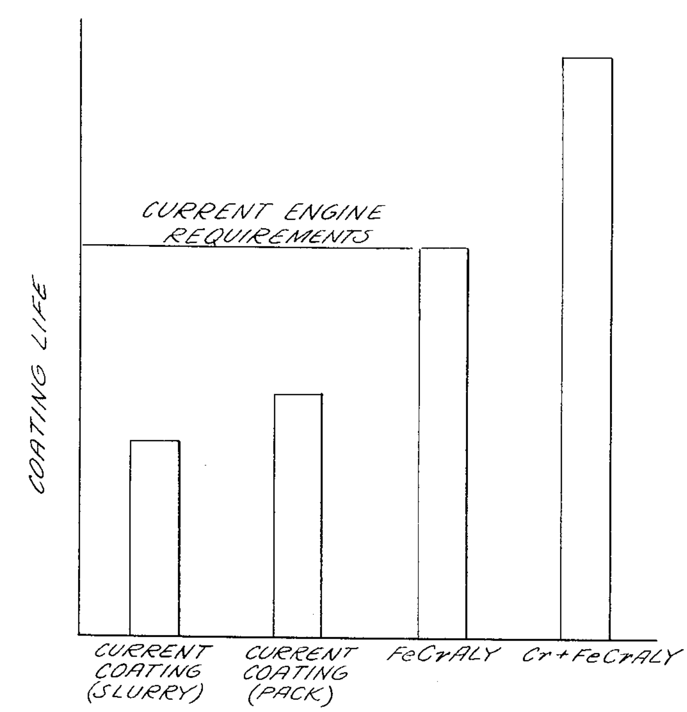
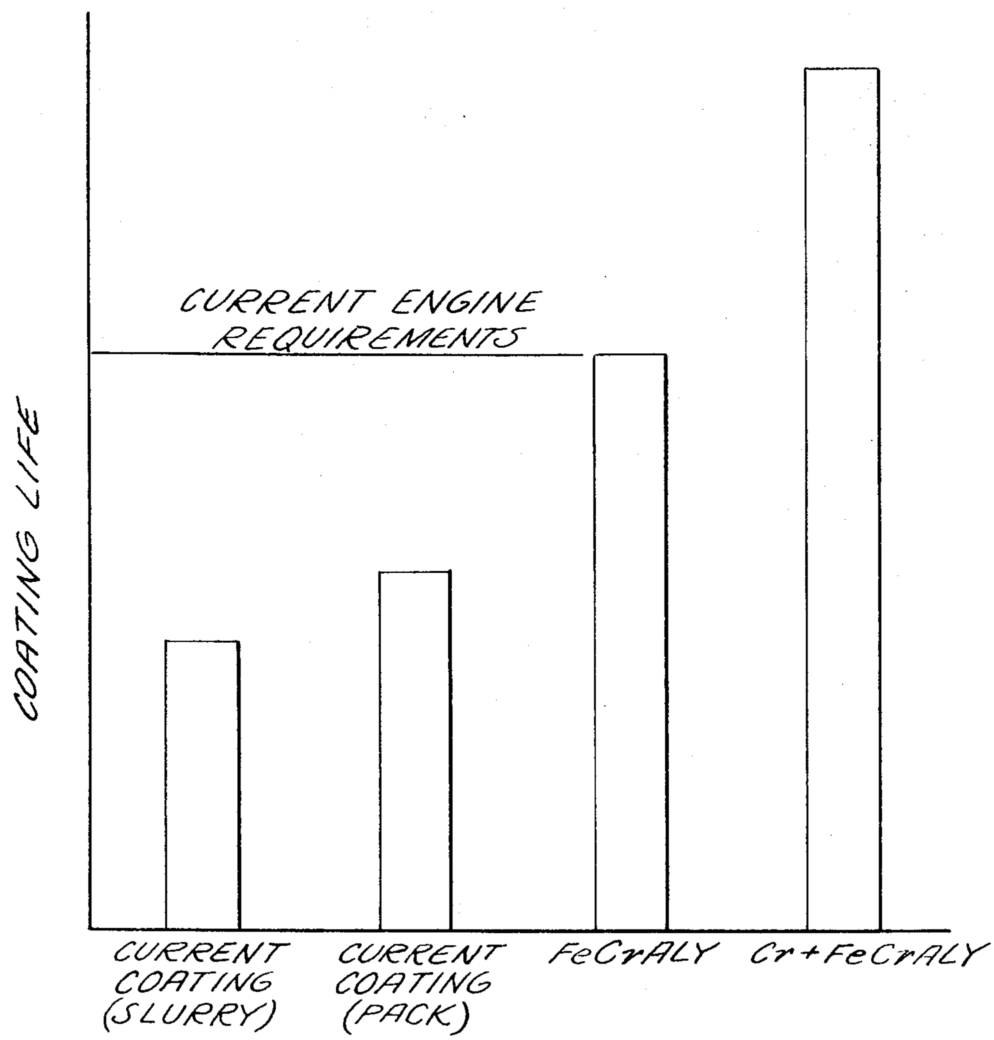
[57] **ABSTRACT**

Improved operating lifetimes are provided for the superalloys through use of a composite coating comprising a chromium or chromium-rich interlayer adjacent the superalloy substrate surface and an oxidation-resistant outer layer comprising an alloy of iron, cobalt and/or nickel alloyed with selected amounts of chromium, aluminum and yttrium.

4 Claims, 1 Drawing Figure





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COMPOSITE COATING FOR THE SUPERALLOYS

BACKGROUND OF THE INVENTION

The present invention relates in general to high-temperature, oxidation-resistant coatings for the superalloys, particularly as applied to gas turbine engine components.

A limiting factor in the application of many of the superalloys to demanding environments such as those encountered by jet engine hardware is their susceptibility to high-temperature oxidation and corrosion. For this reason these alloys are generally provided with suitable surface coatings for increased oxidation resistance. For current operating conditions the most widely used coatings have been provided by reacting aluminum with the alloy to form surface aluminides which preferentially oxidize to form surface oxides through which the transport rates of the oxidizing species are low. Typical of processes of this type is that described in the U.S. Pat. No. to Joseph 3,102,044.

Both turbine blade and vane life in existing engines, and the extent of power increases requiring higher engine operating temperatures, are largely limited by the durability of the coatings. In the past, the inadequacy of current coatings to give long term protection against corrosion at very high temperatures has prevented use of some of the stronger nickel-base alloys, such as B-1900, in applications where their properties otherwise indicate the desirability of their use.

At high temperatures in the dynamic oxidizing environment of a gas turbine engine, temperature fluctuations caused by the mixing of hot combustion gases with cooler secondary air, or those associated with variations in engine power levels, give rise to thermally induced strains in the coatings at the metal-oxide interface which are sufficiently large to spall the protective oxide layer. Furthermore, at a temperature of about 2,000° F., nickel and the nickel-base superalloys begin to exhibit a great alloying affinity for the usual coating constituents, and particularly for aluminum, as recognized in the U.S. Pat. No. to Maxwell 3,450,212. Thus, a loss of coating protection in a dynamic oxidizing environment at very high temperature, involves both an inward and an outward loss of one or more of the protective species.

In a series of copending applications of the present assignee, there are described a number of coating compositions for the superalloys which have doubled the endurance of the coated components at high temperature and have in addition permitted engine performance increases associated with the higher temperatures of current interest. In application Ser. No. 731,650, filed May 23, 1968 for an Iron Base Coating for the Superalloys, now U.S, Pat. No. 3,542,530 there is described a preferred coating alloy comprising, by weight, 25–29 percent chromium, 12–14 percent aluminum, 0.6–0.9 percent yttrium, balance iron, hereinafter referred to as the FeCrAlY coating. In application Ser. No. 795,616 filed Jan. 31, 1969 for a Cobalt Base Coating for the Superalloys, there is described a preferred coating composition comprising, by weight, 19–24 percent chromium, 13–17 percent aluminum, 0.6–0.9 percent yttrium, balance cobalt, hereinafter referred to as the CoCrAlY coating. A NiCrAlY coating comprising, by weight, 20–35 percent chromium, 15–20 percent aluminum, 0.05–0.3 percent yttrium, balance nickel is disclosed in application Ser. No. 734,740 filed June 5, 1968. All of the above coating alloys are resistant of oxidation, thermal spalling, and to interdiffusion with the substrate when compared to alternative coating schemes. However, it has been found that even with these advanced coatings there exists a measure of coating-substrate interdiffusion.

It is known that, in some instances, improved coating performance may be obtained through coating processes involving multiple surface treatments. In the U.S. Pat. No. to Gibson 2,809,127, the surface of an alloy is first chromized and then aluminized to increase the oxidation resistance at high temperature. As in the case of Joseph, supra, the basic oxidation protection in Gibson is dependent upon the reaction of aluminum with the constituents of the substrate at the surface to be protected.

SUMMARY OF THE INVENTION

It is the object of the present invention to provide an improved coating for the superalloys characterized by long term durability in dynamic oxidizing environments at very high temperatures. There is provided a composite coating comprising a chromium or predominantly chromium interlayer at the superalloy surface to be protected and an outer layer of high-oxidation resistance comprising an alloy of iron, cobalt or nickel containing selected amounts of chromium, aluminum and a rare earth element such as yttrium.

In a preferred embodiment of the invention, the composite coating comprises an interlayer of chromium and an outer layer consisting essentially of, by weight, 25–29 percent chromium, 12–14 percent aluminum, 0.6–0.9 percent yttrium, balance iron.

In another preferred embodiment, the composite coating comprises an interlayer of chromium and an outer layer consisting essentially of, by weight, 19–24 percent chromium, 13–17 percent aluminum, 0.6–0.9 percent yttrium, balance cobalt.

BRIEF DESCRIPTION OF THE DRAWING

The drawing is a chart comparing the various coatings for the nickel-base superalloys in terms of durability.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Prior to the generation of the FeCrAlY, CoCrAlY and NiCrAlY coating alloys, and as currently provided in production jet engines, component surface protection has normally been provided by exposing the substrate to aluminum or aluminum vapor at high temperature and promoting a reaction of the aluminum with one or more of the substrate constituents to form protective aluminides. In the FeCrAlY-type coating system, the oxidation protection is effected, not by a coating-substrate reaction, but rather by the coating alloy per se. The coating alloy of itself is oxidation-resistant and relatively immune to thermal spalling and no intermediate coatings are required in terms of the basic function which the coating is to provide, nor in fact is any interdiffusion of substrate or intermediate layer constituents into the coating desired. In the present composite coating, an interlayer of chromium is provided to specifically reduce the outer coating-substrate interdiffusion and by so doing to improve the durability of the coating as demonstrated by an increased operating lifetime for a component so coated.

Thus, the durability of the FeCrAlY-type coatings have been found to be limited not by deficiencies in the oxidation-erosion resistance of the coatings per se, but rather is a function of the extent of aluminum depletion in the coating resultant from the coating-substrate interdiffusion, particularly at temperatures in excess of about 2,000° F.

It was found that a substantial improvement in the endurance of the FeCrAlY-type coatings can be provided by interposing an interlayer of chromium or a predominantly chromium alloy between the outer coating and the substrate to act as a diffusion barrier therebetween, minimizing the depletion of aluminum in the outer coating by this mechanism. This chromium interlayer may be produced by any of the available methods for generating such coatings or surface layers including electroplating, electroplating plus diffusion heat treatment, pack cementation, plasma spray, slurry spray, or any other technique providing a predominantly chromium layer at or on the substrate surface. It is relatively immaterial how the interlayer formed subject, however, to the requirement that the process be one yielding an interlayer composed primarily of chromium.

The FeCrAlY-type outer coatings are typically applied utilizing vacuum vapor deposition methods and apparatus. As explained, the efficacy of these coatings is dependent upon the correct coating alloy composition being deposited on the surface to be protected. These coatings are characterized by high-melting points as alloyed and by diverse melting points insofar as the elemental constituents are concerned. Care must taken in the coating formation process to provide all of the desired coating alloy species in the correct proportions in the coating as applied. Satisfactory results have been attained by vapor deposition in a vacuum utilizing an electron beam heat source, as suggested in the U.S. Pat. No. to Steigerwald 2,746,420.

It should be noted that it is the unique combination comprising the composite coating that provides the coating endurance improvements established by test. One of the incidents of the undesirable coating-substrate interdiffusion, in addition to aluminum depletion in the coating, is contamination of the substrate by the coating constituents. The use of the chromium interlayer has been found not only to prevent such detrimental contamination by the coating elements but also to provide none of itself. In addition, the chromium interlayer adjacent the FeCrAlY coating has appeared to provide no observable detrimental effect on the coating alloy itself nor on its adherence to the substrate.

Tests conducted on several nickel-base superalloy substrates, including such superalloys as B-1900, MAR M200, and NX 188, and on the cobalt-base superalloys such as MAR M302, have indicated that coating life improvements on the order of 50 percent are achieved, as graphically illustrated in the drawing.

EXAMPLE

Various nickel-base and cobalt-base superalloy parts to be coated were embedded in a pack of blended powders composed of, by weight, 84.5 percent alumina, 15 percent chromium, and 0.5 percent ammonium chloride. After purging with argon, the pack was sealed and the parts were chromized at 2,100° F. for 4 hours. In general, surface buildups of 0.002–0.005 in. resulted from pack chromizing under these conditions.

Subsequent to the chromizing operation, parts were mounted in the vacuum chamber of electron beam melting apparatus, preheated, and coated by vapor deposition from a molten pool of coating material in a vacuum of 10^{-4} Torr or better to typical outer coating thicknesses of 0.001–0.005 in.

Following deposition of the outer coating, the coated cobalt-base substrates were heat treated at 1,900° F. for about an hour in vacuum with a cool in a nonoxidizing atmosphere at a rate equivalent to air cool. The nickel-base superalloy substrates after coating, and the cobalt-base superalloy substrates after coating and heat treatment, as coated, were dry glass bead peened at 15N for about 2 minutes in accordance with AMS 2,430. Subsequent to peening the coated parts were heated to 1,975° F. in dry argon or hydrogen, or vacuum; held at heat for 4 hours; and cooled at a rate equivalent to air cooling.

A variety of superalloy substrates were provided with several composite coating combinations, particularly with respect to the outer coating composition. After extensive testing, it was determined that the preferred FeCrAlY outer coating chemistry conformed to the following:

Component	percent by weight
chromium	25–29
aluminum	10.5–12.5
yttrium	0.4–0.9
oxygen	0.03 max.
nitrogen	0.01 max.
hydrogen	0.01 max.
other elements, total	0.5 max.
iron	remainder

The most preferred CoCrAlY coating in the composite coating consisted of:

Component	percent by weight
chromium	21–25
aluminum	12–14
yttrium	0.4–0.9
oxygen	0.03
nitrogen	0.01
hydrogen	0.01
other elements, total	0.5
cobalt	remainder

Although the invention has been described in detail, in its broader aspects it is not limited to the exact details described, for obvious modifications will occur to those skilled in the art.

What is claimed is:

1. A composite article resistant to oxidation at high temperature comprising:
   a substrate selected from the group consisting of the high-temperature nickel-base and cobalt-base alloys having strengths suitable for structural applications in a gas turbine engine environment,
   an interlayer, adjacent the substrate surface and bonded thereto, selected from the group consisting of chromium and its alloys,
   and an oxidation resistant outer layer thereover, bonded to the interlayer, which consists essentially of chromium, aluminum, at least one rare earth element, and at least one element selected from the group consisting of iron, cobalt, and nickel.

2. A composite article according to claim 1 wherein: in the outer layer,
   the chromium content is 15–30 weight percent,
   the aluminum content is 10–20 weight percent,
   the rare earth element is yttrium,
   and the yttrium content is at least 0.1 weight percent.

3. A coated gas turbine engine component comprising:
   a substrate selected from the group consisting of the high temperature, high-strength nickel-base and cobalt-base alloys,
   an interlayer, adjacent the substrate surface and bonded thereto, selected from the group consisting of chromium and its alloys,
   and an oxidation resistant outer layer superimposed on and bonded to the interlayer, the outer layer consisting essentially of, by weight, 25–29 percent chromium, 10–14 percent aluminum, 0.4–0.9 percent yttrium, balance substantially iron.

4. A coated gas turbine engine component comprising:
   a substrate selected from the group consisting of the high temperature, high-strength nickel-base and cobalt-base alloys,
   an interlayer, adjacent the substrate surface and bonded thereto, selected from the group consisting of chromium and its alloys,
   and an oxidation resistant outer layer superimposed on and bonded to the interlayer, the outer layer consisting essentially of, by weight, 21–25 percent chromium, 10–15 percent aluminum, 0.4–0.9 percent yttrium, balance substantially cobalt.

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