ABSTRACT OF THE DISCLOSURE

The oxidation-erosion and sulfidation resistance of the nickel- and cobalt-base superalloys is markedly improved through the use of a coating consisting of cobalt, chromium, aluminum and an active metal such as yttrium, particularly at the composition, by weight, of 15-40 percent chromium, 10-25 percent aluminum, 0.1-5 percent yttrium, balance cobalt.

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of our copending application, Ser. No. 795,616, filed Jan. 31, 1969 now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to coatings and coated articles particularly those having high temperature corrosion resistance in gas turbine engine atmospheres.

A limiting factor in the application of the current superalloys to jet engine uses is their susceptibility to oxidation-erosion and hot corrosion at very high temperatures. For this reason it is the usual practice to coat the superalloys with a composition different from and more corrosion-resistant than the substrate alloy.

Although the aluminate coatings, such as those described in the patent to Joseph 3,102,644, have not provided significant improvements in the lifetimes of the superalloys, further improvements are, of course, desirable. Such an improved coating has been found in the cobalt-chromium-aluminum-yttrium system as described herein.

It has been previously reported that certain cobalt-base alloys can be improved in terms of their oxidation and sulfidation resistance by the addition of small amounts of aluminum and yttrium. One such series of alloys is described in the patent to Roush 3,399,058.

Basically, however, the most closely related prior art has been concerned with providing an alloy with good high temperature strength and workability as well as adequate oxidation and sulfidation resistance, and the chemistries of the various alloys have been formulated on this basis. As coating compositions, however, the prior art formulations are generally unsatisfactory in providing long term surface protection to the nickel-base and cobalt-base superalloys at the temperatures of current interest in jet engines.

SUMMARY OF THE INVENTION

Briefly stated, the present invention contemplates a coating composition comprising, by weight, about 15-40 percent chromium, 10-25 percent aluminum, 0.01-5 percent yttrium and/or the rare earth elements, balance essentially cobalt.

In a more preferred embodiment the coating is formulated to a composition comprising, by weight, 19-25 percent chromium, 12-15 percent aluminum, 0.3-0.9 percent yttrium, balance essentially cobalt, as applied to the nickel-base and cobalt-base superalloys.

DESCRIPTION OF THE DRAWING

The drawing is a series of bar graphs comparing various CoCrAlY coating compositions to aluminate coatings. The CoCrAlY compositions vary from each other by the quantity of yttrium.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The superalloys are those strong, high-temperature materials which find particular utility in the very demanding environments such as gas turbine engines. Representative of alloys of this nature are those identified in the industry as follows:

Nominal composition (percent by weight):

- B-1900: 8 Cr, 10 Co, 1 Ti, 6 Al, 6 Mo, 11 C, 4.3 Ta, .15 B, .07 Zr, balance Ni. 
- IN-100: 10 Cr, 13 Co, 4.5 Ti, 5.5 Al, 3 Mo, .17 C, .75 V, .075 Zr, .015 B, balance Ni. 
- Waspaloy: 19.5 Cr, 13.5 Co, 3 Ti, 1.25 Al, 4.25 Mo, .1 C, .005 B, .12 Zr, balance Ni. 
- WT 52: 21 Cr, 1.75 Fe, 11 W, 2(Nb+Ta), .45 C, balance Co.

Taken as a class, the superalloys exhibit relatively good oxidation resistance at the temperatures associated with the hot section of a jet engine. However, since a compromise has normally been made in the alloy composition to achieve the best balance between strength and corrosion resistance as well as other factors, it is the usual practice to coat these alloys with a composition selected for its high temperature corrosion resistance.

The prior art coatings are, in general, most commonly provided by reacting aluminum with the deoxidized surface of the substrate metal to form a protective aluminate. The aluminate layer in turn oxidizes to form the desired inert barrier. However, because of the complex nature of most of the contemporary alloys, control of the coating composition is difficult and, particularly, after exposure to an oxidizing environment at high temperature for an extended period of time undesirable species may be introduced into the coating or depletion of the aluminum level may occur by diffusion into the substrate metal.

When a number of coating alloy candidates were tested in bulk form, the alloys of the present invention were found to actually be somewhat inferior to several other proposed coatings, such as the iron-chromium-aluminum-yttrium coating alloy, in terms of both its corrosion resistance and ductility. However, unexpectedly, when applied to a superalloy substrate, the cobalt-chromium-aluminum-yttrium alloy within the range of, by weight, 15-40 percent chromium, 10-25 percent aluminum, 0.01-5 percent yttrium, balance essentially cobalt, was found to provide a significant improvement in component lifetime as compared to the other coatings. In some cases to achieve some improvement in ductility, it may be desirable to substitute some nickel and/or iron for the cobalt in the CoCrAlY composition.

Whereas coating alloys of the FeCrAlY-type comprise, in fundamental terms, essentially a single phase solid solution, the CoCrAlY coating of the present invention is a multiphase system, essentially a cobalt-aluminide intermetallic dispersed in a ternary cobalt-chromium-aluminum solid solution. The improved performance of the coated articles of this invention has been found to be the result of a greater thermal stability providing greater resistance to a coating-substrate interdiffusion. This has been proven not only in connection with laboratory specimens but also in actual engine testing.

The basic protective effect of the present coating stems
from the aluminum component. A relatively high aluminum content is, accordingly, preferred from a durability standpoint. Below about 10 percent, there is insufficient aluminum present in the system to provide the desired long term durability in the coating. The upper limit on the aluminum content, on the other hand, is established primarily by mechanical considerations. In fact, at the very high aluminum contents, a low chromium content will be most desirable. In general, the minimum quantities of the elements chromium, aluminum, and yttrium or the rare earth elements are determined by corrosion resistance factors while the upper limits are established by mechanical considerations.

Referring to the drawing, several modifications are presented of the herein disclosed alloy and compared to a conventional aluminide coating. Materials with various concentrations of yttrium have been coated upon engine parts which were operated until they failed in accelerated laboratory tests. In the higher concentrations of yttrium, only less forceful peening could be tolerated without chipping the coating and on some, no peening at all could be done. At the lower range of yttrium, less than about 2 w/o, excellent life was evidenced in the neighborhood of 240 to 330 hours. The peening was done at 17-19 N which densifies the coating and makes it oxidation resistant. At intermediate yttrium concentrations, between about 2 and 5 w/o, peening intensity must be reduced to prevent chipping, thereby reducing the effectiveness of the coating to resist corrosion. However protection of the substrate under these conditions by CoCrAlY is still better than aluminide coatings but the part should then be used in areas where it is not exposed to a very rigorous environment.

Above 5 w/o, the alloy is extremely brittle and cannot be peened, but as seen on the drawing, it can withstand oxidation and sulfidation to extend the life of the part to about 230 hours. The cost of the yttrium in the alloy outweighs many of the advantages which can be gained at these higher concentrations, however. Moreover, because the alloy cannot be densified at these high levels, the coating tends to peel off in large pieces, before and when the end of its life is reached. Thus, we prefer to use less than about 5 w/o yttrium in the alloy.

The preferred coating composition has been established at about, by weight, 19-25 percent chromium, 12-15 percent aluminum, 0.3-0.9 percent yttrium, balance essentially cobalt.

In coating the nickel-base and cobalt-base turbine blades and vanes, the surfaces to be coated are first thoroughly cleaned free of all dirt, grease and other objectional foreign matter followed by conditioning by abrasive blasting. The coating is achieved by vapor deposition from a molten pool of the coating material held in a vacuum chamber at 10⁻⁴ torr or better. The ingot melted has the same chemistry as that of the desired finished coating.

Parts are preheated to 1750° F. ±50° for 5-6 minutes before deposition is initiated and this temperature is maintained throughout the coating operation. Deposition time varies somewhat but is controlled to obtain the preferred coating thickness of .003-.005 inch. Subsequent cooling to below 1000° F. is accomplished in a non-oxidizing atmosphere at a rate equivalent to air cooling. Following the coating step, the parts can then be heat treated for 1 hour at 1900° F. ±25° in vacuum to ductilize the coating and provide for easier peening.

The articles are then dry glass bead peened using .007-.011 inch diameter beads with an intensity equivalent to 19 N. In general, the peening is conducted in accordance with the provisions of the processing specification AMS 2430. The parts are then heated to 1735° F. ±25° in dry argon, dry hydrogen or vacuum; held at heat for 4 hours; and cooled in the protective atmosphere at a rate equivalent to air cooling.

The blades and vanes processed exhibit a coating thickness, excluding the diffused zone, of 0.003-0.005 inch. The diffused zone for the nickel alloys is 0.0002-0.002 inch and for the cobalt alloys is 0.0002-0.0015 inch. It is apparent that modifications and changes can be made within the spirit and scope of the present invention but it is our intention only to be limited by the scope of the appended claims.

As our invention we claim:

1. A coating composition for the nickel-base and cobalt-base alloys which consists essentially of, by weight, 15-40 percent chromium, 10-25 percent aluminum, 0.01-5 percent selected from the group consisting of yttrium and the rare earth elements, balance cobalt.

2. A coating composition for the nickel-base and cobalt-base superalloys which consists essentially of, by weight, about 19-25 percent chromium, 12-15 percent aluminum, 0.01-5 percent yttrium, balance cobalt.

3. A gas turbine engine component comprising a nickel-base or cobalt-base superalloy coated to a thickness of at least about 0.003 inch with a coating consisting essentially of, by weight, about 19-25 percent chromium, 12-15 percent aluminum, 0.01-5 percent yttrium or a rare earth element, balance cobalt.

References Cited

UNITED STATES PATENTS

3,399,038 8/1968 Roush 75—170
3,447,912 6/1969 Ortner et al. 29—182.3
3,462,829 8/1969 Maxwell et al. 29—197
3,477,831 11/1969 Talboom et al. 29—195
3,493,476 2/1970 Lucas et al. 204—37

L. DEWAYNE RUTLEDGE, Primary Examiner
E. L. WEISE, Assistant Examiner

U.S. Cl. X.R.

29—197; 75—171; 117—107