TO: KSI/Scientific & Technical Information Division
Attn: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,697,779

Government or Corporate Employee

Supplementary Corporate Source (if applicable)

NASA Patent Case No. : LEw-1,696-2

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:

YES [ ] NO [x]

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words "...with respect to an invention of ..."

Bonnie L. Woerner
Enclosure
DUPLEX ALUMINIZED COATINGS

Inventors: Michael A. Gedwill, North Olmsted; Salvatore J. Grisaffe, Rocky River, both of Ohio

Assignee: The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, Washington, D.C.

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Related U.S. Application Data

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The surface of a metallic base system is initially coated with a metallic alloy layer that is ductile and oxidation resistant. An aluminide coating is then applied to the metallic alloy layer. The chemistry of the metallic alloy layer is such that the oxidation resistance of the subsequently aluminized outermost layer is not seriously degraded.

9 Claims, No Drawings
OXIDATION RESISTANCE OF THE SUBSEQUENTLY ALUMINIZED AND DISPERSION-STRENGTHENED ALLOYS.

On strong, less environmentally resistant superalloys, a nickel outer layer can be developed by pack cementation, ion plating, sputtering, or electrophoresis. Thus, a failsafe system is provided. The aluminide outer layer has a tendency to be less embrittled by substrate elements. It has a lessened tendency to crack because it is supported by a ductile layer, not a brittle, multiphase layer that is conventionally the case. If a crack occurs in the aluminide outer-layer, the ductility of the underlayer restricts its propagation. Widespread oxidation of the underlayer does not occur because the metallic underlayer is oxidation resistant.

OBJECTS OF THE INVENTION

It is, therefore, an object of the present invention to provide an improved oxidation resistant coating for superalloys and dispersion-strengthened alloys. Another object of the invention is to provide an aluminide coating having long time oxidation and thermal fatigue resistance for these materials.

A further object of the invention is to provide an improved aluminized coating for nickel base and cobalt base superalloys, dispersion-strengthened alloys, composites, and directional eutectics.

These and other objects of the invention will be apparent from the specification which follows.

PREFERRED EMBODIMENT OF THE INVENTION

According to the present invention a ductile, oxidation resistant metallic alloy is initially applied to the superalloy. An aluminide coating is then applied to the metallic alloy.

In order to illustrate the beneficial technical effects of the invention NiCrAlSi and FeCrAlY foil claddings were applied to typical nickel and cobalt base superalloys of the type used in gas turbine engines. The nominal composition of the first mentioned cladding was 18% chromium, 3% to 6% aluminum, 0.5 to 1.5% silicon, and the remainder nickel. The preferred composition was 18% chromium, 4% aluminum, 1% silicon, and the remainder nickel.

The other cladding had a nominal composition of 12% chromium, 3 to 6% aluminum, 0.1 to 1% yttrium, and the remainder iron. The preferred composition was 25% chromium, 4% aluminum, 1% yttrium, and the remainder iron.

These claddings were applied to nickel base superalloys known as IN-100 and WI-52. The nominal composition of the IN-100 alloy was 15% cobalt, 9.5% chromium, 5.3% aluminum, 4.3% titanium, 3.2% molybdenum and the remainder nickel. The nominal composition of the WI-52 was 21% chromium, 11% tungsten, 2.2% iron, 1.9% columbium, 0.9% silicon and the remainder cobalt. The cladlings were also applied to WAZ-20 and NX-188 advanced superalloys and to TD-NiCr dispersion-strengthened alloy. The nominal compositions were, for WAZ-20, 20% tungsten, 6.5% aluminum, 1.5% zirconium, 0.2% carbon and the remainder nickel; for NX-188, 18% molybdenum, 8% aluminum, 0.04% carbon and the remainder nickel; and for TD-NiCr, 20% chromium, 2% thorium dioxide, and the remainder nickel. It is further contemplated that the substrate can be nickel and cobalt base composites and directional eutectic alloys.

Claddings having a thickness of 0.127 millimeter of both materials were applied to the substrate specimens by hot isostatic gas pressure bonding at a helium pressure of 15,000 to 20,000 psi for two hours at 1090°C.
Aluminide coatings were then applied to the claddings by pack cementation at 1900°F to 2000°F in argon using a powder mixture consisting of 1% sodium or ammonium halide, 1% aluminum, and the remainder aluminum oxide. It is also contemplated that the aluminide coating can be applied by a sintered or fused slurry, electrodeposition, physical vapor deposition, ion plating, sputtering, hot dipping, or pyrolysis. The electrodeposition can be of the aqueous, fused salt, or electrophoresis type. The spraying can be either a flame or plasma type.

The system performance was primarily evaluated on the basis of weight change, visual appearance, and metallographic change. Weight change results of furnace tests on NiCrAlSi clad IN-100 and WI-52 at 1090°C for 20 hour exposure cycles were obtained. These tests showed that the clad-cladding alloy was oxidation resistant in that it gained weight in forming a protective alumina and then little further weight change occurred. While NiCrAlSi clad on IN-100 showed a slight turn-around primarily due to spalling, it was more protective than on WI-52. Both bare IN-100 and bare WI-52 lost weight rapidly. Exposure at 1040°C resulted in more protective behavior for both cladding systems for times up to 400 hours.

Metallographic cross sections of the NiCrAlSi cladding on IN-100 showed this system was relatively unaffected by 200 hour cyclic furnace oxidation at 1090°C. NiCrAlSi clad WI-52 showed considerable surface oxide penetration and internal oxidation in the cladding after only 120 hours of tests.

The FeCrAlY cladding was evaluated in cyclic furnace oxidation on IN-100 and WI-52. The 1090°C weight change behavior of the clad WI-52 was almost identical to that of the cladding alloy itself. The clad IN-100, however, showed more rapid weight gain accompanied by significant spalling. A lower exposure temperature of 1040°C resulted in less oxidation attack for the claddings on both substrates.

Metallographic and weight change data obtained after 1090°C furnace tests on the commercial aluminide coatings were compared with similar data with the most protective claddings on each substrate. These comparisons indicated that both the attack on the microstructure and weight changes of the coating and NiCrAlSi cladding on IN-100 were very similar after 200 hours (20 hour cycles) at 1090°C. Here, both protection systems were approximately the same thickness. The FeCrAlY cladding on WI-52 was in much better condition than the completely degraded coating, but it was about twice as thick in the as-clad condition. This ease in controlling thickness is a beneficial technical effect of the overlay or cladding process.

The most promising cladding systems based on furnace testing were the NiCrAlSi clad IN-100 and the FeCrAlY clad WI-52; FeCrAlY clad IN-100 also appeared to have some potential. These systems were subjected to Mach 1 burner rig testing at both 1040° and 1090°C using one hour exposure cycles followed by air blast quenching. Such testing imposed significantly greater thermal stress on the protection system and the surface oxide, especially at the leading edges of the burner rig specimens. The FeCrAlY cladding performed better on both IN-100 and WI-52 than did the NiCrAlSi cladding. The thermal fatigue resistance of these clad systems was markedly superior to that of the aluminide coated systems. In all tests, no cracks were observed in the claddings within the test times. Only the FeCrAlY clad WI-52 performed better in oxidation erosion than the aluminide coating.

Some NiCrAlSi clad IN-100 burner specimens were aluminized to obtain the benefits of both protective systems. Soft ductile cladings had shown superior resistance to thermal fatigue cracking while harder and more brittle aluminide coatings resisted oxidation better. Aluminizing the NiCrAlSi clad produced a markedly improved protection system for IN-100. The system withstood at least 800 hours of Mach 1 burner rig testing at 1090°C. Based on the time to show weight change turnaround, the aluminized cladding was four to five times as protective as the commercial aluminide coating. Its thermal fatigue resistance was about three times better than the aluminide coating.

The primary cause for improvement in thermal fatigue resistance is believed to be the existence of a rather ductile oxidation resistant layer of aluminum enriched cladding under the external aluminide coating. In conventional aluminide coatings on superalloys, a hard, carbide rich zone is typically found here. Benefits may also be derived from the conversion of the relatively simple NiCrAlSi alloy to the aluminide. This aluminide would be expected to contain little of the strengthening elements found in the IN-100.

Several aluminized NiCrAlSi clad WAZ-20, NX-188, and TD-Nicr specimens were tested in cyclic furnace oxidation at 1150°C to see how effective the coating would be for higher temperature applications. The oxidation life of the clad was well in excess of 500 and 300 hours, respectively, on WAZ-20 and NX-188, and slightly more than 600 hours on TC-NiCr. This is a substantial improvement over aluminide coatings alone on these substrates which generally failed well within 100 hours in the same tests.

Burner rig tests at 1090°C and Mach-1 were conducted on aluminized, electron beam melted and physical vapor deposited NiCrAlSi coatings on IN-100 and NASA-TRW VI-A. The nominal composition on the coatings as-deposited is 15% chromium, 4% aluminum, 1% silicon, and the remainder nickel. The nominal composition of NASA-TRW VI-A superalloy is 7.5% cobalt, 6.0% chromium, 5.8% tungsten, 5.4% aluminum, 9.0% tantalum, 2.0% molybdenum, 1.0% titanium, 9.5% columbium, 0.40% rhenium, 0.5% hafnium, 0.1% zirconium, 0.13% carbon, 0.015% boron, and the remainder nickel. After 160 hours of testing in the very severe environment, the specimens showed no evidence of thermal fatigue cracking and the coating had completely protected the superalloy substrates from oxidation and erosion.

While several preferred embodiments of the invention have been described it is contemplated that various modifications may be made without departing from the spirit of the invention or the scope of the subjoined claims. By way of example, claddings of NiCrAl containing one or more of Si, Y, Mn and Th can be used. Also claddings of FeCrAl containing one or more of Y, Si, Mn and Ta can be used.

What is claimed is:

1. A coated article of manufacture comprising a superalloy substrate selected from the group consisting of nickel-base superalloys and cobalt-base superalloys, dispersion-strengthened alloys, composites, and directional eutectics.
5. A ductile, oxidation resistant metallic alloy layer covering said substrate, and an aluminide coating covering said metallic alloy layer.

2. An article of manufacture is claimed in claim 1 wherein the metallic alloy layer comprises a cladding.

3. An article of manufacture as claimed in claim 2 wherein the metallic alloy layer comprises a foil cladding.

4. An article of manufacture as claimed in claim 3 wherein the foil cladding is a NiCrAl alloy containing one or more elements selected from the group consisting of Si, Y, Mn, and Th.

5. An article of manufacture as claimed in claim 4 wherein the foil cladding is an alloy consisting essentially of from 15 to 25% chromium, 3 to 6% aluminum, 0.5 to 1.5% silicon, and the balance nickel.

6. An article of manufacture as claimed in claim 5 wherein the alloy consists essentially of about 18% chromium, about 4% aluminum, about 1% silicon, and the balance nickel.

7. An article of manufacture as claimed in claim 3 wherein the foil cladding is a FeCrAl alloy containing one or more elements selected from the group consisting of Y, Si, Mn, and Ta.

8. An article of manufacture as claimed in claim 7 wherein the foil cladding is an alloy consisting essentially of from 15 to 25% chromium, 3 to 6% aluminum, 0.1 to 1% yttrium, and the balance iron.

9. An article of manufacture as claimed in claim 8 wherein the alloy consists essentially of about 25% chromium, about 4% aluminum, 1% yttrium, and the balance iron.