

[54] **METHOD OF STRIPPING ALUMINIDE COATINGS**

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[52] **U.S. Cl.** **204/146**

[51] **Int. Cl.** **B01k 1/00**

[58] **Field of Search** 204/146, 140

[56] **References Cited**

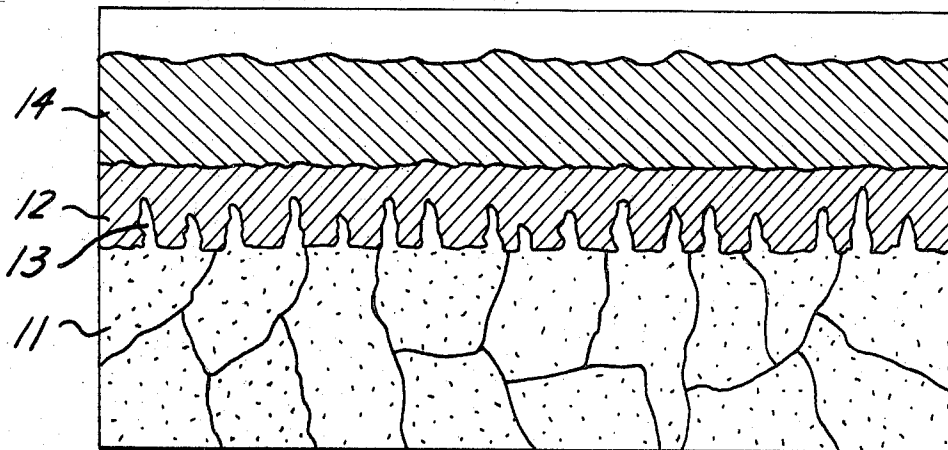
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[57] **ABSTRACT**

A process for stripping aluminide coatings from metals and alloys of the iron group, by making the article to be stripped the anode in an electrolyte comprising an oxidizing acid, at a potential not higher than 2.4 volts.

9 Claims, 6 Drawing Figures



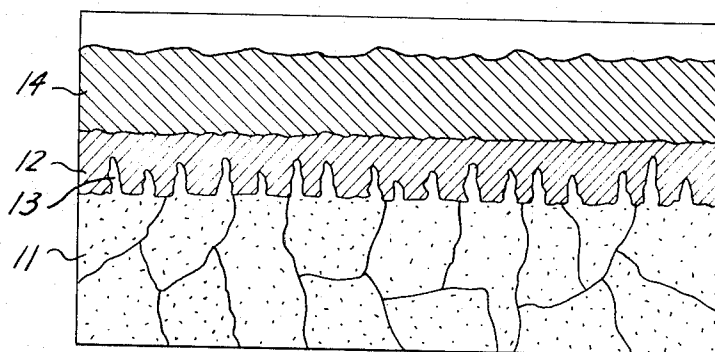


FIG. 1

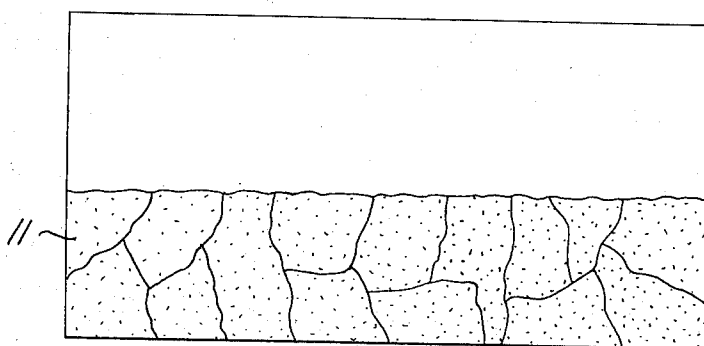


FIG. 2

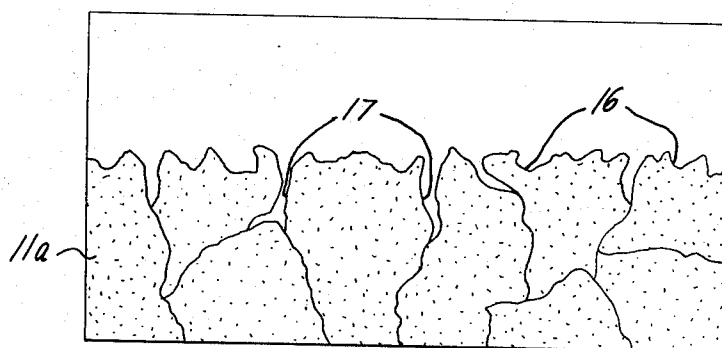


FIG. 3

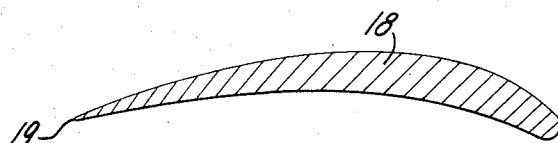


FIG. 4

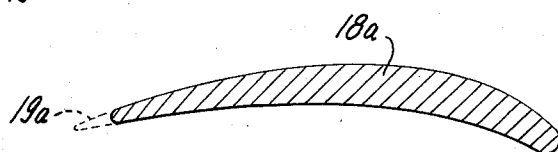
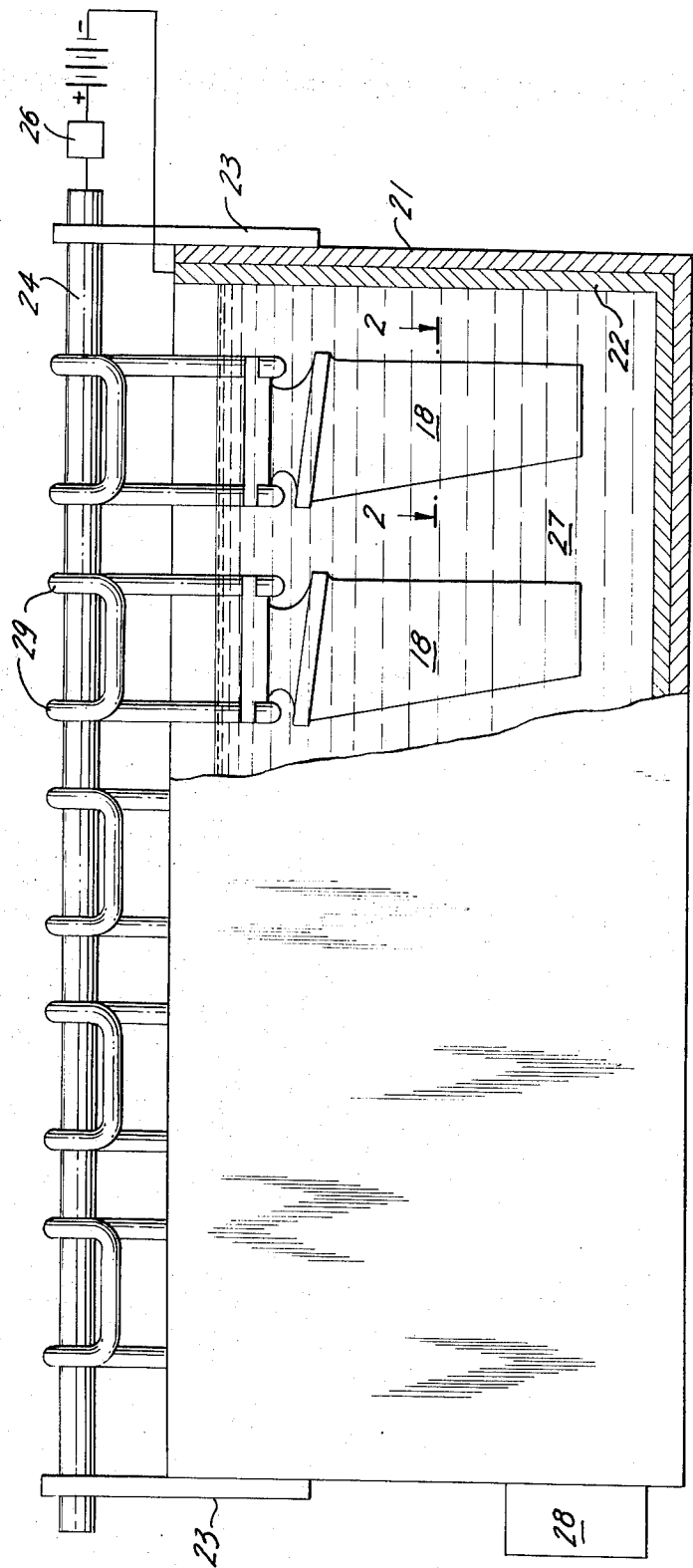


FIG. 5

FIG. 6



METHOD OF STRIPPING ALUMINIDE COATINGS

BACKGROUND OF THE INVENTION

This invention relates to a method of removing a metallic coating from a basis metal, and more particularly to removing aluminide coatings from basis metals of the iron group. The aluminide coating may comprise an aluminide phase of the basis metal, and a surface phase of more or less pure aluminum.

The development of modern aircraft power plants has resulted in a demand for metals capable of withstanding high operating temperatures, such metals being designated superalloys. In the main, they are alloys having a nickel base, cobalt base, or nickel-cobalt base, although some alloys having an iron base are also used. Turbine blades fabricated of such superalloys are exposed not only to high temperatures, but to the very corrosive combustion gases of the turbine, and hence must have high oxidation and corrosion resistance. Although the superalloys inherently have a high degree of such resistance, it is common practice to augment it by aluminiding the surface of turbine blades, that is, diffusing an aluminum coating into the surface of the blades.

Aluminiding is performed by packing the blades in powdered aluminum with a suitable activator, and bringing the pack up to the fusing temperature of the aluminum for an appropriate period of time. Aluminum diffuses into the surface of the blade where it forms an aluminide bond with the basis metal, both in an intergranular manner and into the matrix of the basis metal. The aluminide phase is further overlaid with a phase of pure or nearly pure aluminum.

In overhauling such engines it is necessary to strip the blades of both phases of the aluminum coating, in order to examine the blades for defects such as cracks, incipient cracks, or evidences of corrosion which would indicate a potential weakness of the basis metal. In the prior art such stripping has been done in an electrolytic cell, with the blade as anode in a hydrochloric acid solution and with a driving potential of 6-20 volts. Hydrochloric acid was used because of its vigorous attack on aluminum, shortening the time of the process. However, since it is a reducing acid it also attacks the basis metal unless careful and continuous attention is given throughout the process.

If such careful control is not exercised there may be a serious effect on the dimensional integrity of the blade, such as surface attack producing roughness, intergranular attack with weakening of the structure, rounding off of small radii, change in critical curvatures, and in the case of rotor blades, alterations of the dimensions of the blade root which controls the fit to the turbine rotor. Even though close watch is kept on the process, intergranular corrosion of the basis metal may still occur, principally due to the strong reducing action of the acid, which will result in eventual failure of the blade.

SUMMARY

This invention provides an electrolytic process for stripping aluminide coatings from basis metals and alloys of Period IV Group VIII of the periodic arrangement of the elements, that is, iron, cobalt, and nickel, frequently referred to as the metals of the iron group. As used herein, the term "iron group" includes not only the pure metals but also alloys wherein the major

matrix, that is, more than 50 percent, is composed of one or more of the members of Period IV Group VIII.

The present process employs oxidizing acid solutions and electrical potentials such that the basis metal is passivated wherever it becomes exposed to the acid solution and thus does not react or go into solution, while the reaction with the coating continues at portions not yet fully stripped until all the aluminide coating has been removed, including intergranular penetration and diffusion of the aluminum into the basis metal. Completion of the process is readily visible by change in color of the stripped article.

It is therefore an object of the present invention to provide a process for stripping aluminide coatings from basis metals and alloys of the iron group.

It is another object to provide a process for stripping aluminide coatings wherein the basis metal is not deleteriously affected by the process.

A further object is to provide an electrolytic process for stripping aluminide coatings in an oxidizing acid electrolyte and at such a potential that the basis metals is passivated and does not react with the electrolyte.

Other objects and advantages will become apparent on reading the following specification in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a representation of the metallurgical structure of a superalloy of the iron group bearing an aluminide coating;

FIG. 2 is a representation of the same alloy after removal of the aluminide coating by the process of the invention;

FIG. 3 is a similar representation, on a somewhat larger scale of the grain structure, of a superalloy of the iron group after having had the coating removed by the process of the prior art, showing damage to the basis metal;

FIG. 4 is a cross-section of a turbine blade after removal of the coating by the process of the invention;

FIG. 5 is a cross-section similar to FIG. 4, showing damage to the trailing edge of a blade stripped by the method of the prior art; and

FIG. 6 shows a semischematic arrangement for practicing the process of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Basically, the process comprises the following steps:

1. Degreasing. The articles to be stripped are immersed in a degreasing fluid of the solvent type to remove oil, grease, waxes, resins, and other surface accumulations which are soluble in the fluid. Trichloroethylene, perchloroethylene, and trichloroethane are examples of suitable degreasing fluids of the solvent type.

2. Grit Blasting. The degreased articles are then cleaned of any remaining surface deposits by blasting with grit, such as aluminum oxide, in grains of appropriate size. Grit of sieve sizes No. 100 to about No. 200 are suitable, with about No. 120 considered preferable. Blasting may be done at gauge pressures of about 20 to about 80 psi, with 40-60 psi preferred.

3. Electrolytic Stripping. The parts are immersed in a solution of an oxidizing acid maintained at room temperature, from about 60° to about 90°, with the parts connected as anodes to a source of electrical power at a potential not higher than 2.4 volts. The other pole of

the power source is connected to lead cathodes immersed in the solution, lead having a high resistance to the acids used. The lead cathodes should have an aggregate surface at least equal to that of the parts being processed, and preferably a greater surface. A convenient mode of assuring adequate lead surface is to carry out the process in a lead-lined tank. The distance separating the anodic parts and the lead cathode may vary considerably, with the reaction taking more time as the distance is increased. Where the articles treated are of highly irregular shape such as turbine blades, and hence cannot present surfaces at equal distances from the cathode, a general separation of about 4-6 inches between the parts and the cathode is suitable for reasonably even stripping of the parts.

Suitable oxidizing acids are sulfuric acid and phosphoric acid, at a concentration from about 40 percent to about 60 percent, preferably about 50 percent. Agitation of the solution is provided by any convenient means such as mechanical stirring, oscillation of the means by which the parts are suspended, or by a pump which circulates the solution.

Stripping is continued until all the aluminum is removed, which is readily discernible by the color of the parts. The aluminum or aluminide phase has a gray color which is markedly distinct from the tan or brownish color of basis metals of the iron group when they become exposed.

The time required to completely strip the parts is subject to considerable variation, depending on such factors as temperature, voltage, the concentration of the acid solution, the thickness of the aluminide coating, the kind of basis metal, and the distance between electrodes. At a temperature of about 75°F with fresh solution, an aluminide coating about 0.005 inch thick, and a distance of 4-6 inches between electrodes, the stripping time at a potential of approximately 2 volts is from about 5 hours to about 7½ hours for cobalt basis metals. Nickel basis metals and iron basis metals under the same conditions strip in about 2 to 2½ hours. With thinner aluminide coatings the times are correspondingly decreased. However, there is no adverse effect from an overrun of time, owing to the passivation of the exposed basis metals, as will be explained below. Portions of the parts which may be closest to the lead cathode will be stripped before the remainder, but the reaction will proceed with only the remaining coating without affecting the exposed basis metal.

4. Rinse. When the aluminide coating has been completely stripped, the parts are removed from the stripping solution and rinsed in cold running water for a minimum of one minute, or in several changes of cold water.

5. Scrubbing. Some light smut or sludge may remain on the parts after rinsing. In this case they are scrubbed with a suitable abrasive powder, such as pumice, and a stiff brush. If parts are being processed on a continuous basis with a large throughput, they may be run through an automatic scrubbing machine with rotating brushes appropriately oriented, or tumbled in an abrasive slurry, or handled by other known production means for scrubbing.

6. Final Rinse and Dry. The parts are again rinsed in cold running water or several changes of water, and may then be allowed to air dry. However, for faster processing it is preferable to follow the cold water rinse with a hot water rinse to heat the parts, and then blow

them dry with air, either individually or by running them through a blower chamber. The parts are then ready for inspection, and those which have suffered no deterioration in service may be realuminided and returned to service.

In FIG. 1 there is shown the metallurgical structure of an article formed of a superalloy of the iron group containing chromium as one of the alloying elements, in a cross-section at the surface and transverse thereto. The basis metal 11, a nickel alloy, is shown with its grain structure and having a two-phase coating. The phase 12 is in the diffusion zone immediately adjacent the basis metal, and comprises principally nickel aluminide and some carbides of the basis metal. A sub-phase of elongated fingers 13 projecting from the basis metal into the aluminide is formed of chromium-rich material. The formation of these chromium-rich fingers is due to the diffusion of aluminum into the basis metal, which lowers the solubility of chromium in the nickel of the alloy, causing the precipitation of chromium out of solution in this region. The surface phase 14 comprises practically pure aluminum.

FIG. 2 shows a similar cross-section of the same article after stripping the coating according to the process of the invention. The aluminum phase 14 and the aluminide phase 12 have been removed, and the chromium-rich fingers 13 have crumbled and disappeared, leaving the basis metal 11 exposed, without attack by the stripping solution.

FIG. 3 shows a similar cross-section of a basis metal 11a of the iron group after stripping an aluminide coating by a process of the prior art. The surface 16 has been attacked by the stripping solution, leaving a pebbled appearance when viewed in natural size. There has also been intergranular attack, leaving fissures 17 at the surface which are areas of weakness and offer starting points for eventual cracking of the part.

FIG. 4 is an enlarged cross-section of the airfoil portion of a turbine engine blade 18 fabricated of a superalloy of the iron group, after stripping an aluminide coating by the present process. The trailing edge 19 of the airfoil tapers to a very thin section, varying somewhat according to the size and design of the engine, but frequently having a terminal radius of no more than 0.005 inch. Such a trailing edge very nearly amounts to a knife edge, but nevertheless is not damaged by the stripping process of the invention. It is important that this dimension of the blade should not be altered, since the throat dimension between adjacent blades in an engine is defined by the distance between the trailing edge of one blade and the convex surface of the blade adjacent. The allowable tolerance on the throat dimension in many engines is only a few thousandths of an inch.

FIG. 5 shows, in exaggerated form, the diminution of the blade span of a blade 18a stripped by a prior art process, in which the portion 19a of the trailing edge shown in dotted line has been dissolved in the stripping solution. Such loss of material has a serious effect on the efficiency of the engine when the blade is reinstalled, because of the change in dimension and form of the interblade passages and the consequent undesirable changes in gas flow.

The type of damage shown in FIG. 5 arises from the fact that in using the reducing acid stripping solution of the prior art the basis metal will be attacked wherever exposed, even though stripping may not yet be com-

plete at other portions of the surface of the object; and this attack will be accentuated if the exposed portion happens to be a relatively sharp edge, owing to the high concentration of the electrical field at edges and corners, especially with the higher voltages of the prior art.

Since turbine blades have a very complex geometry and it is impossible to position such a blade in the solution in such a manner that all parts of its surface will be at equal distances from the cathode, it is inevitable that the closest portions will be stripped first of their coating. The basis metal at such a first-stripped portion, if a reducing acid is employed, will begin to react and will be dissolving while the remainder of the article is being stripped. If the closest portion happens to be a thin section such as a trailing edge, part of it may entirely disappear before the remainder of the blade is stripped, when using the reducing acid and high voltage of prior art processes.

With the oxidizing acids of the present process and a potential not higher than 2.4 volts, exposed basis metals and alloys of the iron group become passivated and do not react with the electrolyte. Chromium also participates in this characteristic, so that although it is one of the principal alloying elements of superalloys of the iron group its presence does not diminish the suitability of such superalloys for treatment by this stripping process.

Anodic polarization of the metals and alloys of the iron group and of chromium results in the passivation of these metals. Passivity is attributed to the formation of metal-oxygen complexes at the anode surface which make the signal potential of the anode more positive and hinder its solution. Such metal-oxygen complexes may occur either by the formation of a very thin film (micron thicknesses) of the metal oxide on the surface of the metal, or by the formation of a solid solution of the oxide in the anode metal at the surface.

Such passivity of the anode metal forming the object to be stripped can only be maintained at low voltage, 2.4 volts having been found to be the highest potential at which the process can be practiced. At higher potentials the driving force of the voltage will dislodge the oxide film or the solid solution of oxides, and the basis metal will be propelled toward the cathode. However, the only lower limit is 0 volts. The disadvantage of operating at a lower potential than necessary is that the time of stripping is increased. A convenient practical potential for practicing the process on the metals and alloys of the iron group, whether containing chromium or not, is 2 volts.

It should be pointed out that the process is not characterized in terms of current density, the operative conditions being the potential difference between the anode and cathode, in a solution of an oxidizing acid. Hence, precise spacing between the anode and cathode is not critical. Although a spacing of 4-6 inches has been given as a convenient distance when stripping turbine blades, it was chosen to promote relatively even stripping of the complex surfaces of the blades. The distance could be considerably increased with the only effect being increase in the time required. Further, if the articles to be stripped have flat surfaces which can be opposed to flat cathodes, or if anode and cathode have some other configuration allowing parallelism of their respective opposed surfaces, the separation between the electrodes can be greatly diminished and the processing time shortened.

FIG. 6 shows an embodiment of equipment suitable for stripping articles according to the process of the invention. A tank 21 of any suitable material is provided with a lead lining 22. The tank bears appropriate supporting means 23 for positioning an anode rod 24 or other anode means above the tank. Although the supporting means 23 is here shown as brackets attached to the tank shell, the anode rod may equally well be supported and positioned by any convenient means, not necessarily attached to the tank. The power supply for the process may be batteries putting out an appropriate voltage, or may be the available line current with a variable voltage rectifier 26 interposed. The positive output is connected to the anode means 24 and the negative terminal to the lead lining 22 of the tank. The tank is filled with a solution of an oxidizing acid 27, for which an agitating means 28 is provided, which may be a circulatory pump as shown or other appropriate means.

A plurality of articles to be stripped of aluminide coating, in this case turbine blades 18, are suspended immersed in the electrolytic solution of oxidizing acid, from metal brackets 29 which are hooked on the anode rod 24. It is to be understood that the suspension means may have any form adapted to the articles to be processed, as long as it is a conductor which makes the anode connection. Following are examples of the practice of the process on aluminided turbine blades.

EXAMPLE I

The articles to be stripped were turbine stator blades having a basis metal formed of a superalloy of the iron group known as Inconel 713C, a trademark of the International Nickel Company, having the following nominal composition:

Carbon	— .12%
Chromium	— 13.00
Aluminum	— 6.00
Molybdenum	— 4.50
Columbium plus	Tantalum — 2.00
Titanium	— .60
Manganese	— 0.50
Silicon	— 0.50 max.
Cobalt	— 1.00 max.
Iron	— 2.50 max.
Nickel	— Balance

The blades had an aluminide coating of approximately 0.005 inch in thickness. They were degreased in trichloroethylene for approximately 5 minutes, with agitation. The blades were then blasted with No. 120 grit at a gauge pressure between 40 and 60 psi until they appeared visually clean of any surface deposits.

The blades were then suspended in a lead-lined tank containing a solution of about 50 percent by volume of sulfuric acid at room temperature, with the blades connected as anodes and the lead lining connected as cathode to a power supply maintained at 2 volts. Relative agitation between the blades and the solution was provided. Within one hour the gray color of aluminum began to disappear from portions of the blades and the brownish color of the basis metal (chiefly nickel) began to appear. After two hours the blades showed the brownish color of the basis metal throughout, but the stripping procedure was continued for another half hour as a precautionary measure.

The parts were then removed from the electrolyte and rinsed in cold running water for a minimum of one

minute to remove the acid. They were then scrubbed with pumice and a stiff brush until the metallic color of the predominantly nickel basis metal appeared. They were then further rinsed in cold running water to remove any traces of sludge, dipped in hot water, and blown dry with air. Subsequent metallurgical examination showed that all traces of the aluminide coating had been removed.

EXAMPLE II

The parts to be stripped were sections cut from airfoil portions of turbine blades formed of Inconel 713C having the same composition as that discussed in Example I. The surface of the airfoils had an aluminide coating of about 0.003 inches in thickness; however, where the blades were cut in two the basis metal was exposed from the beginning.

The parts were degreased and grit-blasted as in Example I. Thereupon they were suspended in the tank containing a solution of about 50 percent by volume of phosphoric acid, with the parts connected as anodes at a potential of 2 volts. The exposed basis metal of the cut portions took on the typical brownish hue within a few minutes. Within less than an hour the gray color of aluminum had disappeared from considerable portions of the airfoil surface, being replaced by the brownish hue of the basis metal. After an hour and a half the removal of the aluminide coating appeared visually complete, but the parts were left in the solution for another half hour.

The parts were then rinsed and cleaned as previously described. Metallurgical examination showed no attack of the basis metal, even of the portions which had been exposed before processing, and the aluminide coating had been entirely removed.

EXAMPLE III

The articles to be stripped were turbine blades having a basis metal formed of a superalloy of the iron group known as HS 31, or Stellite 31, a trademark of the Haynes Stellite Company, having the following nominal composition:

Carbon — .50
Chromium — 25.00
Nickel — 10.00
Manganese — .60
Silicon — .60
Iron — 1.00
Tungsten — 8.00
Cobalt — Balance

The parts had an aluminide coating about 0.005 inches in thickness. They were degreased and grit-blasted as in Example I, then suspended in a lead-lined tank containing a solution of about 50 percent by volume of phosphoric acid with the parts connected to the power supply as anodes and the lead as cathode, with the potential being maintained at 2 volts, and agitation

of the solution provided. The brownish color of the basis metal, chiefly cobalt in this embodiment, began to appear after a few hours, and on some articles the gray color of aluminum could no longer be discerned after five hours. However, some articles still bore traces of aluminum which did not entirely disappear until after seven hours of processing. The parts were then left in the solution under voltage for a further half hour as a precautionary measure. They were then removed from the electrolyte, rinsed, scrubbed, again rinsed, and dried as in previous examples. Metallurgical examination revealed complete removal of the aluminide coating without any attack on the basis metal.

EXAMPLE IV

Sections were cut from the airfoil portion of turbine blades of HS 31, having an aluminide coating of about 0.003 inch, and processed as in Example III, except for using sulfuric acid as the electrolyte. After five hours of treatment the coating appeared to have been entirely removed. Processing was continued for a further half hour, and the parts then cleaned and dried. Examination showed that all the coating had been removed, and that the basis metal had not been attacked at any portion.

What is claimed is:

1. A process for stripping the coating from an article formed of a basis metal of the iron group and having an aluminide coating thereon, comprising cleaning the surface of the coating, submerging the article in an oxidizing acid having a lead cathode therein, connecting the article as anode to the positive pole of a source of electric power and the cathode to the negative pole thereof, and applying a potential difference less than 2.4 volts between the anode and the cathode until the aluminide coating is removed from the article.

2. A process as recited in claim 1, wherein the oxidizing acid is at a concentration from about 40 percent to about 60 percent.

3. A process as recited in claim 2, wherein the oxidizing acid is selected from the group consisting of sulfuric acid and phosphoric acid.

4. A process as recited in claim 3, wherein the acid solution is maintained at a temperature from about 60° to about 90°.

5. A process as recited in claim 4, wherein the basis metal of the article is predominantly nickel.

6. A process as recited in claim 5, wherein the basis metal is Inconel 713C.

7. A process as recited in claim 4, wherein the basis metal is predominantly cobalt.

8. A process as recited in claim 7, wherein the basis metal is Stellite 31.

9. A process as recited in claim 1, wherein exposed basis metal becomes passivated and is not attacked by the oxidizing acid.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,779,879 Dated December 18, 1973

Inventor(s) Bruce E. Scott

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

IN THE SPECIFICATION:

Column 3, line 18, the word "precent " should read --percent--

Column 4, line 34, the word "viwed" should read --viewed--

Column 5, line 32, the word "signal" should read --single--.

Signed and sealed this 7th day of May 1974.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents