An On-site Process to Repair IVD Aluminum Coatings

Christopher J. Helwig, Brooktronics Engineering, Valencia, CA

IVD coatings are a recognized alternative to cadmium electroplating for corrosion protection applications. This process is used extensively throughout the airframe of today's commercial aircraft. IVD aluminum coatings have several beneficial characteristics in addition to corrosion protection. These include a deposit that is compatible with dissimilar metals and will not cause hydrogen embrittlement of high-strength steels. Up to now, however, there has not been a practical way to repair this coating on site. The current procedure is to remove the part, strip off the coating and re-coat the part in a vacuum chamber. A new coating, which was also developed as a cadmium replacement, has shown that it can be deposited over an existing IVD aluminum and the bare steel base metal, which has been exposed. This coating can be applied on site, without having to remove the damaged part. It has excellent corrosion protection, is compatible with different metals and does not cause hydrogen embrittlement of high-strength steels.

For more information, contact:
Christopher J. Helwig
Brooktronics Engineering
28231 Avenue Crocker, Bldg. 70
Valencia, Ca 91355
Phoen: 805/294-1195
FAX: 805/294-9032

Back ground

IVD Aluminum Coatings were designed and accepted for use as an alternative process to Cadmium electroplating for corrosion protection. IVD Aluminum coatings were shown to have several advantages to conventional immersion plating, these include:

- Excellent corrosion resistance.
- No detrimental galvanic interactions with dissimilar metals.
- No hydrogen embrittlement of high strength steels.
- No fatigue strength loss in aluminum alloys due to anodizing.
- Environmentally safe.

As a result of these benefits (1), IVD Aluminum coatings are used extensively in the Aerospace industry on airframes and other aircraft components.

IVD aluminum is deposited onto the surface of the components by use of a vacuum chamber called an Ivadizer. The process deposits an almost pure aluminum coating. This coating can them be glass beaded and chromate coated for extra corrosion protection. The Ivadizer is a large and somewhat complex piece of equipment; this has limited the number of these installations. However, as IVD aluminum coatings become more popular, the number of these installations will also increase.

Problem

IVD Aluminum coatings require damaged parts to be placed into a vacuum chamber for re-coating. Therefore, problems can arise with repair and maintenance of coated components. Damaged coatings on airframe and other assemblies can occur during normal flight operations and maintenance activities. When this damage occurs, the IVD coating loses its effectiveness and up to now, there has not been a practical way to repair the coating with out removing the part, stripping off the old deposit, and returning it to the Ivadizer for re-coating. This can result in serious problems, such as scheduling delays and costly down time of the aircraft.

Solution

After a review of existing methods of applying corrosion protective materials, we felt that brush electroplating was a very credible method of achieving such a repair. Brush electroplating can be performed directly on an airframe or any other piece of equipment, with out having to completely disassemble the component. Brush electroplating will provide a dense, adherent deposit that will provide excellent corrosion protection. The question remained, which deposit would be right for the job.

On going tests of Cadmium replacement deposits, have provided valuable information on several electro-deposits that have excellent corrosion protection. These deposits were primarily Zinc-alloys. Previous studies on these alloys showed that an alloy of Tin-Zinc had many of the characteristics we wanted to incorporate. These characteristics included a deposit that had excellent corrosion protection, was ductile, had good throwing power into corners and threads, low contact resistance and most importantly, showed no signs of bi-metallic corrosion due to the presents of dissimilar metals (2). The only real problem that was found with this Tin-

Zinc alloy was that it was soft and therefore, highly susceptible to mechanical damage. After further study, it was decided to increase the amount of zinc in the deposit to 55-65% in order to harden the deposit for better durability.

The Zinc-Tin deposit was originally designed as a replacement for cadmium; therefore, it was tested using the Cadmium plating specification, QQ-P-416 as a guideline. The tests included;

- Salt spray testing for corrosion resistance.
- Hydrogen embrittlement testing of non-post plate notched bars
- Deposit compatibility with dissimilar metals.
- Deposit adhesion.

The results of these tests proved that Zinc-tin is a viable replacement for cadmium plating. (3)

The success of the previous tests provided one important feature for our IVD Aluminum repair material, that of corrosion protection. Other tests were then designed to test the performance of this coating. Again, these tests were unique to brush electroplating because this process must work in ways that conventional electroplating and mechanical deposition processes such as vacuum or metal spray can not.

Testing Procedures

Any material that was to be used as a repair for IVD Aluminum must be able to perform at least as well as the IVD aluminum coating. A testing regiment was set-up to determine the performance capability of the Zinc-Tin alloy. The tests checked corrosion protection, deposit compatibility with other metals and the adhesion of the deposit over both the aluminum coating and base material such as steel. This deposit was tested under the guidelines of various ASTM standards and MIL-C-834488C, which provides the performance criteria for IVD Aluminum deposits. A summary of these tests is provided in the following text.

Corrosion

In this test, we combined procedures to determine the corrosion protection of the Zinc-Tin deposit along with the deposit compatibility with dissimilar metals present in the repair area. Up to now the typical repair procedure would be to simply remove the component, strip off the existing coating and re-coat the entire part. Brush plating is a portable process that can selectively plate areas of a component with out having to remove it from the assembly. The process for this repair is simply to remove loose or damaged coatings, prepare the surface and plate onto the damaged area. Therefore, a deposit must be compatible with the base metal and the existing coating. This includes no galvanic interaction between the IVD Aluminum, the base metal and the Zinc-Tin deposit, which would be detrimental to corrosion protective coating.

For this test, we used four coupons of 15.2cm x 10.1cm x .064cm (6in x 4in x .025in) 4340 steel test coupons. These coupons were masked down the center with a strip of .635cm (.25in) wide tape. The panels were then coated with IVD Aluminum. The panels were then glass beaded and chromated. Two panels were coated to MIL-C-83488C class 1 type II and the other two were coated to class 1 type I. The masking was removed exposing the bare steel (Fig.1). The panels were then masked, exposing the bare steel and approx. .64cm (.25in) of IVD Aluminum material on either side of the steel (Fig.2). The area was then plated with Zinc-Tin to a thickness equaling the IVD coating; .003cm-.0038cm (.0013in-.0015in) for class 1 deposits and .0013cm-.002cm (.0005in-.0008in) for class 2 deposits (Fig.3). The panels were Chromate coated for a type II deposit (Figure 4) and subjected to salt spray testing in accordance with ASTM-B117. Panels were checked for two characteristics. The first to determine if the coating could pass the corrosion protection requirements of IVD Aluminum. The other, to determine if any galvanic interaction is taking place between the base metal, The IVD Aluminum coating and the Zinc-Tin alloy that would speed up the deterioration of the base metal.

Hydrogen Embrittlement

IVD Aluminum coatings do not cause hydrogen embrittlement of high strength steels. Therefore any material used to repair this coating must also have the same benefit. Brush plating is used quite often as a repair procedure over existing metals on components that are part of a larger or more complex piece of equipment. For this reason, there is no practical way to perform a post plate bake. This Zinc-Tin alloy solution had to be designed so it could be electroplated over metals such as high strength steel, with out needing a post plate bake to remove the hydrogen.

A notched bar test was run using bars made from 4340 steel. These bars conformed to MIL-S-5000, condition E4 and were prepared according to ASTM F-579 Type 1A specifications. The specimens had a nominal notched root diameter of .445cm ± .012cm. (.175in ± .005in), a notched radius of .025cm ± .001cm (.010in ±.0004in) and an average notch tensile strength of 340,000 psi. The notched bars were prepared using a standard preparation procedure for high strength steel (Table 1). These bars were plated to a nominal thickness of .0012cm (.0005in). After plating, the bars were then chromated for a type II coating. The parts were then air dried and sent to a testing lab. The parts were subjected to a room temperature, notched tensile-hydrogen embrittlement test. The specimens were loaded and subjected to a sustained load, equivalent to 75 percent of the average notched bar strength of non-plated samples. This test was run for 200 hours or until a sample failed. This test was repeated after six months using the same bar lot and the same solution batch. This was done to test the repeatability of the test and to give the material a starting shelf-life value.

Adhesion

The adhesion of the Zinc-Tin alloy onto dissimilar metals is vital for its use as a repair for IVD Aluminum. This deposit must be able to adhere to both the Aluminum coating and base metal such as steel. In this instance the coating as well as the preparation procedure has to be proven. Adhesion testing for brush plating deposits, particularly those of less than .0025cm (.001in) is performed using a tape test per MIL-STD-865C. MIL-STD-865 was developed as a guide to brush electroplating quality standards and describes this test more detail: A 1in. Wide strip of 3M* code 250 tape (or equivalent) is applied to the surface using hard pressure. The tape is then pulled off quickly at a 90-degree angle.

The test coupons we used were 2.54cm x 10.1cm (1" x 4") 4340 steel coupons. The coupons had been masked across the 2.54cm line with a .635cm (.25in) wide piece of tape. The part was then coated with aluminum in accordance with MIL-C-83488C type 2 class II. The coating thickness was .0013-.0020cm (.0005-.0008in). The tape was then removed exposing the bare steel band across the middle of the coupon. The bare steel and a area of 1.27cm (.5in) on either side of the bare steel was activated in accordance to the activation procedure called out in table 1 and plated to thickness equivalent to the IVD coating. The part was then tape tested to test adhesion. Later, the part was then bent at 90 degrees along the edge of the convergence of the three metals and was tape tested along the deformity.

TEST RESULTS

Corrosion-Galvanic Interaction

The test panels that were submitted to the salt spray chamber were periodically checked for red rust corrosion on the surface. The panels were also checked to determine if any accelerated corrosion formation was developing along the interface of the 4340 steel, IVD Aluminum and the Zinc-Tin deposit. The results of the testing (Table 2) showed the first and only failure of these panels occurred on one of the type II panels at the 2,157hour mark. In addition, there were no signs of accelerated corrosion occurring along the interface line of the different metals. Indicating no detrimental galvanic interaction between the metals.

Hydrogen Embrittlement

The results of hydrogen embrittlement test (Table 3) show no failures on test bars. The test was ended at 200 hours and the coating was determined no to cause hydrogen embrittlement and is therefore safe to use on metals such a high strength steel with out the need of a post plate bake.

Adhesion

The test for adhesion of the Zinc-Tin alloy was also a test to determine if the preparation of the IVD Aluminum and the steel base metal would be compatible enough to have the Zinc-Tin alloy adhere to both metals. The results of this test showed no failure on either the flat tape test or the 90-degree bend test-tape test. Zinc-Tin deposits can therefore be said to adhere to either of these metals equally well.

Summary

The results of this testing have shown that this Zinc-Tin alloy can deposit a coating that can be used for the on-site repair of IVD Aluminum coatings. The alloy originally designed and used as a Cadmium replacement has the ability to protect a steel base metal from corrosion. This Zinc-Tin alloy has also been shown to be compatible with an existing IVD Aluminum coating and the steel base metal. Corrosion testing showed no galvanic interaction between the Zinc-Tin repair deposit, existing IVD Aluminum and the steel base metal. Another important feature of this product is that the Zinc-Tin can be deposited onto a repair site with out the problem of hydrogen embrittlement something that is unique to brush plating. Finally the deposit and the preparation procedure were tested in regards to bonding characteristics on dissimilar metals. The results showed that the material along with the process could deposit this repair material with equally good adhesion on the different metals present.

With the success of these tests, Zinc-Tin has shown itself to be a viable repair procedure for the repair of damaged IVD aluminum coatings. Brush electroplating is a low cost, portable process that produces little waste and is easy to learn and maintain. The continuing development of new products such as this zinc-tin alloy illustrates the importance of this process to the Aerospace and industries in general.

Reference:

1. D.E. Muehlberger and J.J. Reilly " Improved Equipment Productivity Applications for Ion Vapor Deposition of Aluminum" , 19th Annual Airline Plating Forum, March 1983

2. E. Budman and R.R. Sizelove "Zinc Alloy Plating", 1999 Metal Finishing guidebook, P.P. 338-345

3. C.J. Helwig "Zinc-Tin, a Choice for Replacement of Cadmium for Brush Plating Applications", 1998 Aerospace/Airline Plating & Metal Finishing Forum, March 1998

Table I
Abrasive Blast Preparation procedure 4340 Test Bars and Coupons

1) Degrease and clean the work piece.

2) Mask as necessary, This masking will be used to guard against abrasive over spray as well as solution plating boundaries

3) *Abrasive-blast the work area.* For best results the abrasive should impact the surface at about a 45degree angle. Blasting should continue until the surface has an even, matte finish without shiny areas or discoloration.

4) Wet the surface with the Zinc-Tin plating solution without using voltage. Add voltage to the electrode and begin to plate over the entire activated surface.

Material used is Virgin Aluminum Oxide with a grit size range of 100 to 220.
Air pressure should be set at 40-80 PSI.

Table II
Salt Spray Corrosion-Galvanic Interaction Test Results

Coupon	Base Metal	Coating Type	Test Method	Results
1	4340	Zn-Sn/IVD Al Type II Class 2	Salt Spray	3,068+ Hrs.
2	4340	Zn-Sn/IVD Al Type II Class 2	Salt Spray	3,068+ Hrs.
3	4340	Zn-Sn/IVD Al Type II Class 1	Salt Spray	3,068+ Hrs.
4	4340	Zn-Sn/IVD Al Type II Class 1	Salt Spray	2,132 Hrs.

Note: Coupons were run to red rust corrosion.
Test was terminated at 3,068 hours.

Table III
Hydrogen Embrittlement Test Results

Coupon	Base Metal	Coating Type	Test Method	Results
Test #1				
1	4340	Zinc-Tin, chromated	Notched Bar	Passed
2	4340	Zinc-Tin, chromated	Notched Bar	Passed
Test #2				
3	4340	Zinc-Tin, chromated	Notched Bar	Passed
4	4340	Zinc-Tin, chromated	Notched Bar	Passed

Table IV
Adhesion Test Results

Coupon	Base Metal	Coating Type	Test Method	Results
1	4340	Zn-Sn/IVD Al Flat coupon	Tape Test	Passed
2	4340	Zn-Sn/IVD Al flat coupon	Tape Test	Passed
3	4340	Zn-Sn/IVD Al 90 deg. Bend	Tape Test	Passed
4	4340	Zn-Sn/IVD Al 90 deg. bend	Tape Test	Passed

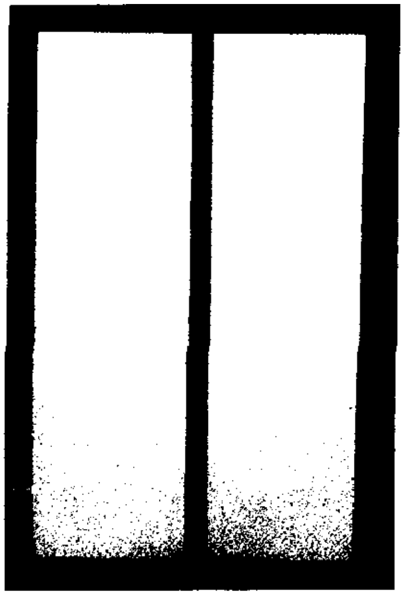

Figure 1.
IVD Aluminum Panel with bare 4340
Base metal strip

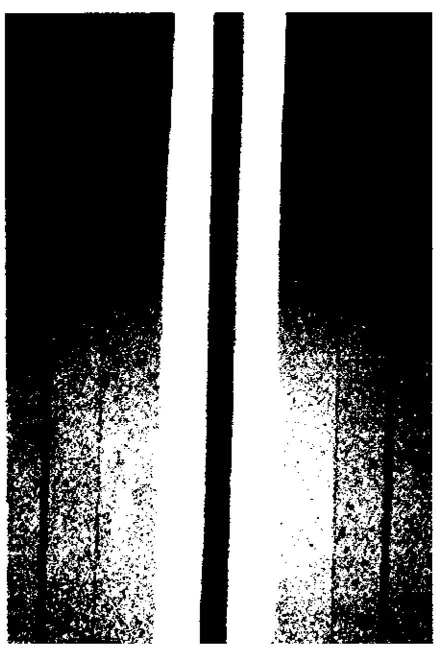

Figure 2.
IVD Aluminum panel masked for Zinc-Tin
Plating in center area

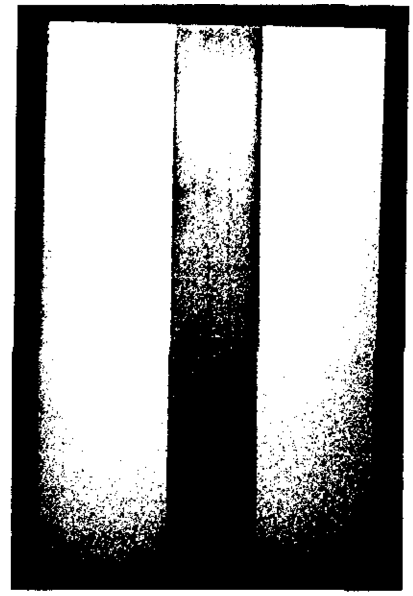

Figure 3.
Center of panel plated with Zinc
Tin deposit

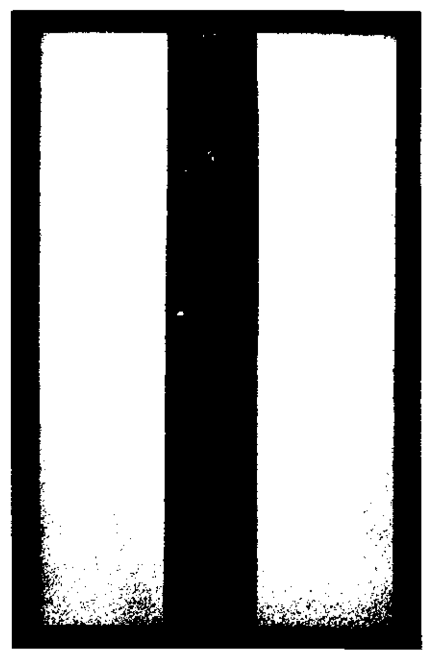

Figure 4.
Center deposit of Zinc-Tin
chromated for salt spray testing