Zinc-Tin: A Choice for Replacement of Cadmium For Brush Plating Applications

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There have been many papers written concerning cadmium replacement. Brush electroplating concerns, like their counterparts in conventional electroplating, have also been working toward the goal of replacing cadmium with a deposit that is easy to use and compatible with existing metal deposits during repair procedures. Conventional bath tin-zinc alloy solutions have been described in papers as interesting, but not complete replacement for cadmium plating. This paper details performance characteristics of a zinc-tin brush plating solution that is a suitable replacement for cadmium plating.

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BACKROUND

Cadmium and its compounds have been designated as environmental hazards by environmental organizations around the world. Both industry and government agencies have been working on suitable replacements technologies. These replacement deposits must provide comparable performance standards, which are found in existing Cadmium coatings. Several materials have gained acceptance as replacements for Cadmium; these include Zinc alloys and Ion Vapor Deposited Aluminum. (1)

The brush electroplating industry has also been working on suitable replacement coatings. The process of brush electroplating is unique in that it eliminates the need for electroplating baths. The process uses hand held or fixtured electrodes to introduce the plating mechanism directly to the effected surface as noted in figure 1. By using this procedure, metal parts, which have become damaged or worn, can be repaired, in many instances, in place. The repair of parts in place (in situ) can save both time and money by eliminating the need for disassembly and the downtime of waiting for the part to be processed and returned by a conventional tank plating facility. Brush plating solutions can be applied directly to a specified area. This not only reduces the need for masking but it also keeps the solution volume low. This low volume, along with the fact that the solution may be used repeatedly, results in lower volumes of waste being generated using this process. However, with the ever restricted use of cadmium, brush electroplating companies have also had to look for replacement technologies.

Alloy deposits have been discussed in some length as suitable replacements for Cadmium. In this report, a Zinc-Tin alloy was tested and was found to have very good corrosion resistant properties. However, brush electroplated deposits must do more than just protect against corrosion. Typical brush electroplating applications, unlike conventional Tank electroplating processes, deposit metal in the localized area of the needed repair. Rarely does this process involve stripping off of the existing coatings and the re-plating of the entire part. In most cases the newly deposited metal will be plated over the existing cadmium coating and the bare steel base metal. Therefore, the new deposit must be compatible with the other metals present. This compatibility includes the ability to bond to several metals at a time with an absence of any galvanic processes which may be detrimental to the component or the other metals present. Zinc-Tin was selected for testing because alloys of this deposit were found to have low contact resistively, good ductility, and are free of bimetallic corrosion. (2)

The alloy, which was chosen, has a nominal composition of 35-45 percent tin and 55-65 percent zinc. This is a higher concentration of Zinc than has been tested and discussed in previous studies. The increased percentage of zinc was used to increase wear resistance and hardness of the Zinc-Tin deposit. Hardness testing of this alloy gave this deposit a hardness of 50 Knoop. This hardness was definitely lacking in other Tin-Zinc alloys.(3) The increased Zinc in the alloy also lends itself to post plate conversion coatings to increase corrosion protection of the deposit. Brush electroplating deposits, as with other electroplating deposits have the potential to introduce hydrogen into the plating interface. This hydrogen can

be usually expelled by baking the part after plating. In a brush electroplating repair procedure, it is impractical to perform a post plate bake on a part because it is usually still part of a larger assembly. Therefore, the solution, which is used, must be designed so that it will not introduce hydrogen into the existing part.

TESTING PROCEDURES

A testing regiment was set-up to determine the performance capability of the Zinc-Tin alloy. This deposit was tested under the guidelines of various ASTM standards and QQ-P-416, which provides the performance criteria for Cadmium plating. Tests were run to check corrosion protection, hydrogen embrittlement, and compatibility with existing Cadmium coatings and adhesion. A summary of these tests is provided in the Text.

Corrosion

Corrosion tests were run on deposits of Zinc-Tin which were chromated (type II) and others which were left bare (type I). The test specimens were 15.2cm (6.0 in) x 10.1cm (4.0 in) x .064cm (.025 in) 4340 test coupons. The Coupons were plated on one side only with the Zinc-Tin alloy. Samples were plated at room temperature (65-75 degrees F.) at a current density of .6-. 96 amps per square cm (4-6 amps per square in). These panels were plated with the Zinc-Tin solution to a thickness of .0010cm-.0015cm (.0004-.0006 in). The deposit thickness was checked using a Deltascope Thickness gauge. The panels were lightly burnished after plating and

chromate was applied to the applicable panel. 7 months later with the same solution lot an additional test was run with the same parameters as the test just described. In each test, the plated panels were then subjected to salt spray testing in accordance with ASTM B117. The panels were placed on a plastic rack and exposed to a 5 percent salt mist. These panels were checked periodically to determine the condition of the deposit. It was also noted that, because, only one side of the panel was plated, corrosion which started from the back side and creeping around an edge was not grounds for failure. These panels were tested until the presence of red rust could be determined to be coming through the plated deposit.

Hydrogen Embrittlement

Hydrogen Embrittlement testing was performed to determine the ability of the solution to deposit a coating of Zinc-Tin on high strength steel substrates without causing embrittlement of the material due to Hydrogen. Separate tests, 7 months apart were run to show repeatability of results and test the effective shelf life of the Zinc-Tin solution. Both tests used notched bar samples which had come from the same test sample lot, BH. These bars were made of 4340 steel conforming 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 (.175in) $\pm$ .012cm (.005in), a notched radius of .025cm (.010in) $\pm$ .001cm (.0005in) 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 I) These bars were then plated with Zinc-Tin to a nominal thickness of .0011cm (.0005 in). After the plating was completed, the surface was lightly burnished and chromated. The parts were then rinsed, dried and sent to a lab for testing. The test, which was performed on these parts, was a room temperature notched tensile-hydrogen embrittlement test. The specimens were loaded and subjected to sustained load tests at applied stresses equivalent to 75 percent of the average notched bar strength of unplated samples. The test was run for 200 hours or until a test piece failed. In both tests, 4 samples were run.

Adhesion

Adhesion of any electroplated deposit will greatly depend on the quality of the surface preparation. Plating of Zinc-Tin deposits require the same surface preparation as does Cadmium or most any metal. Adhesion tests for brush plated deposits, particularly those of less that .0025cm (.001 in) are typically performed by a tape test. MIL-STD-856 was developed as a guide to brush electroplating quality standards. In accordance with this specification, a 2.54cm (1 in) wide strip of 3M* code 250 tape (or equivalent) is applied to the plated surface with heavy pressure. The tape is then quickly removed in one 90 degree pull. Any metal adhering to the tape is cause for rejection. In a more severe test, sample coupons of 2.54cm 1 in x 10.1cm (4 in) x .064cm (.025 in) were plated to thickness of approx. .0013cm (.0005 in) and bent in a 90 degree angle. Tape tests were then performed at the sight of the deformity.

Deposit Compatibility

The deposit compatibility test was designed to determine the compatibility of a brush plated repair over existing Cadmium on a steel substrate. For this test we chose a coupon of 4130 steel. This coupon had a plating area of 10.16 cm (4 in) x 10.16 cm (4 in). In the middle of the coupon, a piece of 2.54cm (1 in) wide tape was placed effectively dividing the work piece into three distinct areas. The area was then plated with Cadmium to an approx. thickness of .0018cm (.0007 in). The tape was then removed exposing the bare steel mid section of the part. The Cadmium plated surfaces on either side of the bare steel were masked off, with the exception of the 1.02cm (0.4 in) area adjacent to the steel base metal. The 4.57cm (1.8 in) area of cadmium and steel was then plated with Zinc-Tin, again to a thickness of approx. .0018cm (.0007 in). The Zinc-Tin was plated at a current density of 0.6-9.6 amps per square cm (4-6 amps per square in). When the plating was completed, the parts were lightly burnished, chromated and sent to the lab for salt spray testing per ASTM B117.

TEST RESULTS

Corrosion

The corrosion test was run until evidence of red rust corrosion appeared on the plated surface. The results of the testing (table II) showed that the first, non-chromated Zinc-Tin sample demonstrated red-rust corrosion between 572-596 hours. The second panel was tested to the 504-528 hour mark before red rust corrosion was noted. The deposit of the first Zinc-Tin deposit which was chromated, was tested and red rust was observed between 740-812 hours. The second test panel which was chromated was observed to have red rust corrosion beginning on the outside and spreading inward at the 768-840 mark. This panel was then left in to continue testing until red rust was observed on the center of the panel. This was noted at the 912-1008 hour mark.

Hydrogen Embrittlement

The results of Hydrogen Embrittlement testing showed no failures. (table III) The four bars in each test were run to 200 hours and survived. It has been determined that this solution does not cause hydrogen embrittlement on high strength steel and can be used for repair procedures on high strength steels without the need for a post-plate bake.

Adhesion

The adhesion of the Zinc-Tin was proven to be as good as the existing Cadmium plated surface. Tape tests on flat samples of Zinc-Tin and Zinc-Tin plated over Cadmium resulted in no failures of the plating deposits. Bend tests of the same samples also resulted in no failure of the plating in the deformed areas. (Table IV)

Deposit Compatibility

The results of this test showed that after 1000 hours, no corrosion products were found on the Cadmium, the Zinc-Tin or the interface between the two deposits. The result showed no detrimental galvanic activity between the two deposits, therefore the Zinc-Tin is compatible with existing Cadmium plating in a repair scenario.

SUMMARY

A Zinc-Tin brush plating solution was developed to replace Cadmium for the repair of damaged or worn areas on existing parts. As a brush plated deposit, this material must have some unique performance criteria. This solution must be easy to use, plate at room temperature and adhere to several different metal substrates at a time. As a substitute for cadmium plating, this material must be able to pass the performance criteria for cadmium electro-deposits as outlined in QQ-P-416. This deposit must also be able to be plated on high strength steels without a post plate bake and not cause hydrogen embrittlement. The test results have shown that this material meets the requirements listed above and should be considered as an alternative to Cadmium plating. Further testing should also be performed in order to establish values for hardness, wear resistance and temperature limitations. However, the most valuable characteristic of Cadmium plating is corrosion protection and the Zinc-Tin solution, which was tested, has been shown to be at least an equal.

REFERENCES

1. Stopki, J.T. and Graham G.H.," Evaluation of Zinc Alloys As An Alternative to Cadmium"., 31st Annual Airline Plating Forum pp. 13-24

2. Budman, E., "Zinc Alloy Plating", *1995 Metal Finishing Guide Book*, pp. 324-329

3. Ibid.

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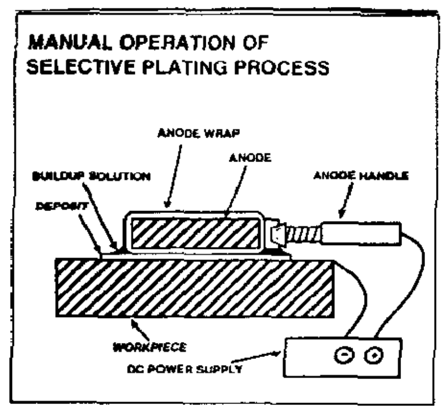

Figure 1. The mechanism of brush electroplating

Table I
Preparation procedure for high strength steel

When Hydrogen Embrittlement of the base metals is a concern, all Electrochemical preparatory steps must be performed on reverse polarity.

1. Remove any surface oils or grease with an appropriate solvent. Remove visible oxides films or corrosion products chemically or mechanically.

2. Electroclean, setting the machine at 10-15 volts on reverse polarity. Continue until a consistent soap film is observed and no water breaks appear on the surface.

3. Rinse with water.

4. Etch the work area, set the machine at 5-10 volts on reverse polarity. Continue until the surface has a consistent matte or etched appearance.

5. Rinse with water.

6. Desmut, set the machine at 5-10 volts on reverse polarity. Continue until the surface does not become any lighter.

7. Rinse with water.

8. Plate with Zinc/Tin solution, set the machine at 5-15 volts on forward polarity and plate to the desired thickness. A chromate coating may be added for type II applications.

Although the above procedure works, concerns persist when any form of acidic, electrochemical solution is used on high strength steels. Therefore, alternative, mechanical methods of metal preparation are used. These methods include using an abrasive blast procedure with virgin 120-220 grit Aluminum Oxide. The procedure is simply blast the surface to get a consistent appearance and plate.

The other method uses Scotch Brite™ to scour the surface. This procedure is also very simple, pre-wet the Scotch Brite™ pad with the plating solution and scour the surface until there are no water breaks. When this is complete, you may start plating and continue to the desired thickness.

Table II
Salt Spray Corrosion Test Results

Coupon	Base Metal	Coating Type	Test Method	Results
Test #1				
1	4340	Zinc-Tin, non-chromated	Salt Spray	572-596 Hours
2	4340	Zinc-Tin, chromated	Salt Spray	740-812 Hours
Test #2				
3	4340	Zinc-Tin, non-chromated	Salt Spray	504-528 Hours
4	4340	Zinc-Tin, chromated	Salt Spray	768-840 Hours

Note, the second Zinc-Tin, chromated sample (4) was run to 912-1008 hours before red rust was observed in the middle of the part.

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	Zinc-Tin, flat coupon	Tape Test	Passed
2	4340	Zinc-Tin, flat coupon	Tape Test	Passed
3	4340	Zinc-Tin, 90 deg. Bend	Tape Test	Passed
4	4340	Zinc-Tin, 90 deg. bend	Tape Test	Passed