Important Considerations In Hard Chromium Plating

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Hard chromium plating is generally recognized as one of the key elements of support components for high-performance aircraft engines and landing gear. Major developments in functional chromium plating systems, especially engineering (or hard) chromium, are few and far between, but reliability and performance criteria in aircraft components, both miltary and commercial, are maintained at exceedingly high levels. Assessing the numerous requirements placed on the performance of the hard chromium deposit, it suggests that the operator, and all concerned engineering/maintenance, quality control and supervisory personnel, examine the basics involved in the overall plating scheme.

The "bottom line" in the quality plating of aircraft components is the production of a completely plated part that passes all inspections with an extended service life. Without surveillance or continuous monitoring, long service life is difficult to forecast, but is best ensured by overseeing important factors in the plating operations—from pretreatment to final bake (if used)—and by developing an inspection routine.

But what *are* the important considerations for hard chromium plating; how do they affect product quality; and how much attention to this operation is required?

Equipment & Pretreatment Issues

Beginning with equipment, there are elements of each step or component of the plating system that require continuing examination. For the sake of simplicity, the elements in this category are broken down to include: tanks and linings, heating and cooling systems, devices for bath agitation, pumps, power sources, anodes and various pretreatment steps. Plating problems may arise because of faults with each piece of equipment, or with each step in the process. Fortunately, however, probable causes can be isolated and corrective measures can be proposed.

Tanks & Linings

The basic system for hard chromium plating includes a container for the plating solution. Welded steel tanks lined with either antimony or tin-lead sheet provide durable protection, unless workpieces contact the metal sides. Linings should be brought up to and over the edge to ensure sealing and to maximize support. Where lining sheets are used, it is wise to check joints to determine if a "lead burning" seal has been employed and is holding up.

The use of steel tanks lined with polypropylene or with treated polyvinyl chloride also is acceptable but care must be taken to ensure that jigs, fixtures or parts themselves do not puncture the plastic during loading or unloading. Iron contamination, stray currents and other serious problems develop when the tank lining is ruptured.

Heating & Cooling

Practical heating systems vary for each installation, and depend on tank size, operating temperature, type and volume of parts, and economics of energy sources. If heating systems malfunction, leaks may develop or overheated equipment may be damaged. To protect the bath, the workpieces and the overall plating tank, periodic examination of the thermoregulators is suggested.

Cooling systems, which, for chromium plating, can employ simple cooling coils that circulate tap water or, at the extreme, cooling towers, are quite effective. Like heating systems, however, these units must be examined periodically. If heating or cooling coils are used, they should be insulated at inlet and outlet junctures to minimize the effects of stray currents.[1-3]

Bath Agitation

Whereas many platers today regard stirring or agitation as an incidental task in chromium plating, many of the early proponents recognized its importance.[1,4-6] Air agitation and mechanical stirring are used most commonly. Air lift pumps and air manifolds usually present no problems themselves, but trace amounts of oil can be introduced through air-agitation systems without oil traps or filters. In many systems, the workpiece does the mixing by virtue of a cathode rod agitator. Grease and oil, potential contaminants generated from these systems, should be checked regularly, along with bath constituents,[7] during routine analysis of solutions.

Pumps

During chromium plating, pumps are used to transfer solution from one tank to another, and, importantly, to introduce fresh solution to tubular or complex recessed shapes of the workpiece. Pumps also are used to increase solution flow and to channel solution through filtration systems. Today (1980), many hard chromium platers are using or considering filtration, either periodically or on a continuous basis. Contamination of baths can be reduced greatly by using proper filters, usually made of polypropylene, glass fiber or other proprietary fiber cartridges. Pumps should be constructed on non-corrodible materials, such as high-silicon cast iron, Hastalloy C, rigid PVC or high-density polyethylene.

If other materials are used, pumps should be lined with a suitable synthetic. Properly constructed pumps, pipes, fittings and support systems that come in contact with plating solution are essential to minimize corrosion and prevent damaging solution contamination.[2,3,8,9]

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Power Sources

These units, usually rectifiers or motor generators, contribute to faulty plating when the ripple output exceeds 5 percent, when switches or other controls permit unsteady current supply, or when current-regulating equipment becomes defective.[1,8] The latter must provide smooth and accurate on-load control without current interruption, and fully automatic systems should be considered.

Systems designed for high voltages (more than 16V) and for reversing current, when needed, favor the motor generator; but ripple, usually caused by the commutator or by periodicity, should be checked to eliminate any occurrence of laminated deposits and faulty cohesion. Individual links in the electrical system, including bus bars, should be examined regularly for electrical bonding faults—corroded contacts or any circuit joint not firmly attached.[2]

Anodes

Lead-alloy anodes serve two key functions in the chromium plating bath: (1) providing effective current distribution and (2) reoxidizing trivalent chromium to the hexavalent form. Chemical lead anodes are sometimes used in an emergency, but prolonged use results in attack by the bath and in the development of voluminous amounts of lead chromate sludge. Suggested precautions include using anodes thick enough to sustain high current and prevent severe warping, which might result in an electrical short.[3,6]

Anodes should be checked for extra heavy or irregular buildup of lead dioxide to prevent problems in current distribution.[10] Heavily worked baths and those with closely conforming anodes require periodic cleaning of anodes. Acid dipping, alkaline soaking and scratch brushing, plus electrolytic reduction techniques, are useful to remove the semi-insulating coating. Most lead anodes tend to "passivate," because of the formation of insoluble chromate or fluoride, when left in chromium plating baths unused for some time. The anodes then must be "energized" with full tank voltage for a period of several minutes to possibly an hour before they are fully reactivated and conductive.[1,3,8]

Pretreatment

This area constitutes all cleaning and surface area preparation performed on the workpiece before plating. Cleanliness is of paramount importance. Grease and oil can create numerous problems throughout the entire plating operation if not completely removed. Special solvents, hot alkaline solutions and emulsion cleaners are most effective cleaners if not overloaded with impurities—oil and other foreign debris—but should be checked routinely for maximum allowable concentration. The absence of smut or waterbreak on the surface of the workpiece is a general indication of cleanliness.[11]

Historically, platers have depended on the chromium plating bath to aid in the cleaning step, and, in many shops, chromic/sulfuric acid solutions are used *alone* as the cleaner. However, in the case of the hard chromium system, which is relied upon to work effectively around the clock for days at a time, the cleansing action of the bath is overtaxed and a defective chromium plate can result.[3]

If a component requires either iron or nickel plating to reach proper physical dimensions before a heavy chromium layer is deposited, the workpiece must be given special attention to make sure its surface is "active" before entering the chromium bath. Poor adhesion can be eliminated by a procedure such as cathodic treatment in 50 vol% sulfuric acid at 4 to 6V for 15 to 20 sec.[12]

Most steel parts develop improved adhesion when conditioned anodically in the plating bath at 6V for up to 1 min or in a highly concentrated chromic acid solution. Excellent adhesion has been reported using an anodic etch in sulfuric acid (specific gravity 1.53) for about 1 min at 25°C (77°F).

Grinding, if performed improperly, can be a source of preplate problems.[13] Old chromium is occasionally activated for replating instead of stripping,[14] but the deposits must be checked for soundness prior to use.[15] The original condition and surface treatment of the basis metal[6] can have a significant influence on the plated chromium ... its crack pattern[16,17] and physical prioperties[18,19] of the final deposit. Crack-free chromium is often desired and, depending on bath makeup,[20,21] has many relationships in its development to the pretreatment of the basis metal and to the early plating conditions.[22-24]

Plating Issues

Bath concentration, solution makeup,[25] operating temperature and power setting usually are sufficiently well-planned by the operator, and so preclude lengthy discussion about one system versus another. The main question, and point of discussion here, is: "What if some unforeseen difficulty arises?"

Let's look at a number of troublesome areas and review possible corrective measures.

No Deposition

When no deposit appears on a part removed from the plating tank, a problem in one of three areas can be anticipated: (1) an electrical malfunction, (2) excessive catalyst concentration in solution or (3) contaminated solution. It is rare that these problems would occur simultaneously.

To correct an electrical problem, the operator should determine if he has a working circuit or continuity. If not, he should make sound all electrical connections. This is easily accomplished by cleaning all contacts in the system.

If the catalyst concentration is too high (differing measurable from the original ratio), excess sulfate should be removed by treatment with barium carbonate. Should tests reveal the solution to be contaminated with excess chloride, the bath should be treated with silver carbonate (which can be reprocessed and reused) or electrolyzed at high current density to drive off the chlorine as gas. Use of this latter method should be limited to shops that have proper equipment for handling the off-gas.

Partial Coverage

Four major occurrences often contribute to partial deposition of chromium on the workpiece. These are: (1) poor electrical contact, resulting in high resistance; (2) poor racking or fixturing; (3) out-of-balance solution or (4) excessive trivalent chromium in solution.

For poor contacts, corrective steps include carefully checking racks/fixtures or jigs plus connective wiring. Anode contacts should also be checked and adjusted if improperly connected. Each rectifier phase should be examined for an electrical short or an internal malfunction. Last, fuses or breakers on all circuits should be checked.

For problems with racks, jigs or fixtures, the design and layout should be checked for unwanted shielding. The workpiece should be repositioned so that gas generated during plating can escape easily. The workpiece also should be examined for open holes. If found, holes can be closed with plastic bags to eliminate continual gas pockets or generating sites.

If analysis proves the solution is out of balance, catalyst concentration should be adjusted. Excess sulfate should be removed by barium carbonate precipitation. If catalyst, especially sulfate, needs to be added, only small quantities (0.15 g/L; 0.02 oz/gal) should be introduced at one time.

If the concentration of trivalent chromium is high (above 22.5 to 30.0 g/L; 3.0 to 4.0 oz/gal), the deposit may be slightly softer than usual and deliver only marginal coverage. Remedies include replacing part of the bath with fresh hexavalent chromium solution or electrolyzing the bath using low-anode current density and high temperature. This procedure may be administered overnight or during a weekend.

Many platers fail to realize that a small amount of trivalent chromium is necessary for effective operation.[3,4] Well-maintained anodes, plus proper anode area in the tank (based on surface area of the workpieces) is essential to maintain the continual reoxidation of the trivalent species to the hexavalent.[2,10]

Whereas a low operating temperature and a reduced chromic acid concentration probably improve throwing power, a high concentration of trivalent chromium tends to work against the system.[6] Determining the exact amount of trivalent chromium in the solution is helpful in making timely adjustments. Effective analytical procedures for this purpose include the ferrous ammonium sulfate method and the potentiometric technique.[7]

Poor Coverage

On occasion, a plater will discover that a workpiece has areas of incomplete plating or less-than-desired thickness. These problems may result from one or more of the following factors: (1) bath temperature too high, (2) racks/fixtures improperly positioned, (3) electrical problems, including high current resistance, too low or too short a striking voltage or too low a current density,[26] (4) catalyst concentration too high or (5) a passive nickel surface, if nickel is used for buildup.

Remedies for these situations include:

- Decreasing bath temperature and perhaps increasing current density[1]
- Rechecking jigs / fixtures or racks to determine if maximum throwing power is attained by the arrangement employed
- Checking for accidental shielding[26]
- Removing anode scale, if identified[3]
- Removing excess sulfate with barium carbonate
- Reactivating passive nickel with a dip of 10% HCl or with a cathodic treatment in 10% sulfuric acid

Dull Spots & Patches

Hard chromium platers are usually not too concerned about cosmetic appeal of the final plate because grinding may be employed afterward. However, dull spots and patches, if detected early, may point to more serious problems, including solution imbalance.[1,9] These blemishes are caused by: (1) poor contacts on fixtures or jigs, (2) partial shielding by a workpiece or by a portion of the rack/fixture and (3) improper rinsing before plating. These are simple enough to control.

Low Deposition Rate

Low deposition rate is of concern to a hard chromium plater if he is trying to meet a production schedule for moderate to heavy deposits. General causes range from contamination and out-of-balance solution to problems with current density and temperature. Bath contamination with chlorides, iron or trivalent chromium is readily handled, once identified. Chlorides are removed, as mentioned, by precipitation[3,7] and high current density electrolysis. If the solution is out of balance, it may need an adjustment with chromic acid or removal of excess sulfate with barium carbonate.

To handle problems with current density, voltage should be adjusted or, for short-term favorable results, the size of the load should be decreased. If solution temperature is too high, an increase in current is suggested while the bath is cooling down.

Poor Adhesion

This is one thing that cannot be tolerated in hard chromium plating. Poor adhesion must be detected early. Factors that lead to unsatisfactory adhesion are pretreatment-oriented, electrical in nature or a result of the condition of the basis metal.

Oil, grease or oxide scale on the surface of the workpiece suggests that cleaning operations should be checked and that a descaling step may be necessary prior to cleaning. Electrical problems may include current interruption (requiring inspection of contacts) or an imbalance in the etching cycle. In the latter case, the etching bath must be examined for proper composition and the current density must be checked. Etching time may have to be readjusted. The condition of the basis metal or any of the deposits (nickel, iron, etc.) used to build up salvaged parts prior to chromium plating should be examined. Nickel should be active and tightly bonded. Chromium should be stripped, or, if double-plated, activated for maximum adhesion[1,3,8] using pulsing[27] or differing bath compositions.[4,9]

Discolored Surface

A discolored surface on thick chromium deposits is a warning of an impending problem. An iridescent color usually suggests low sulfate concentration. Brown spots normally indicate the existence of poor contacts. Each can be corrected easily, once noticed, during plating or between loading of batches.[1,5]

Soft Deposits

Hard chromium platers normally have no desire for soft deposits and try to maintain conditions that will prevent them. Some of the potential causes are: (1) temperature too high, (2) chromic acid concentration too high and (3) trivalent chromium in solution too high.

Corrective steps include reducing the heat or activating the chiller/cooling coils. In the case of a high concentration of chromic acid, determined by analysis, dilution and current-adjusting steps (plus normal attrition) should restore the proper range. Excess trivalent chromium can be eliminated after reoxidizing to hexavalent chromium by raising the temperature and by electrolyzing at low current density.[26] Soft chromium can be expected from some fluoride baths, if not carefully controlled, and much work has been performed in comparing hardness to crack patterns[28,29] and physical properties.[15,30]

Rough Deposits

These types of deposits normally result from occluded metallic impurities in solution, an unbalanced bath or electrical factors. Metallic impurities (grinding dust, slivers or foreign dust) can be removed by filtration, in most cases, and often by magnetic treatment (separation) of the magnetic contaminants. The unbalanced bath will result from low temperature or low catalyst concentration, in this case. Corrective measures are straightforward. Electrical factors influencing roughness include high current density and faulty circuits in the etching system.

Pitted Deposits

Pits will develop in the chromium plate if "tramp" material is in the bath, and if faulty preplate operations and/or problems with jigs, fixtures or racks[31] are existent.

Tramp material, which ties itself to the surface and creates gas bubbles, usually is filtered but sometimes skimmed from the surface. Review of preplate operations may reveal pits in the basis metal before cleaning, ground-in particles that were not removed or surface discontinuities that proper surface grinding would correct. Covering power is also affected by some of these preplate problems.[29] Racks and fixtures, with parts mounted, should be studied to determine if excessive gassing is occurring.

Surface Characteristics

Deposits revealing "milkiness," a "frosty" appearance and gray or burnt finishes can be corrected by recognizing the following potential causes:

- Temperature too low (frosty or burnt appearance)
- Temperature too high (milky character)
- Current density too high (frosty, burnt look)
- Current density too low (milky deposit)
- Interrupted/intermittent current (gray surface)
- Unbalanced bath, in which catalyst or chromic acid concentration is incorrect (milky appearance)
- Poor electrical contacts and improper spacing (burnt deposit)
- Inactive surface (gray deposit)
- Bath contamination with chloride or iron (frosty deposit)

Numerous tests have been developed for analyzing chromium during and after plating [9,28,29] and for examining the material produced,[15,18,19,30] but many of these need be used only sparingly if care is exercised when observing the system specified above. *P&SF*

References

1. P. Morisset, *Chromium Plating*, Robert Draper, Ltd., Teddington, Middlesex, UK, 1954; p. 59-347.
2. J.D. Greenwood, *Heavy Deposition*, Robert Draper, Ltd., Teddington, Middlesex, UK, 1970; p. 135-198.
3. F.A. Lowenheim, *Modern Electroplating*, 3rd ed., John Wiley & Sons, New York, NY, 1974; p. 87-115.
4. W. Blum and G. Hogaboom, *Principles of Electroplating & Electroforming*, 3rd ed., McGraw-Hill, New York, NY, 1949; p. 337-348.
5. R. M. Burns and W. W. Bradley, *Protective Coatings for Metals*, 2nd ed., Reinhold Publishing, New York, NY, 1955, p. 221-233.
6. A.T. Vagramyan and Z.A. Solov'eav, *Technology of Electrodeposition*, Robert Draper, Ltd., Teddington, Middlesex, UK, 1961; p. 192-304.
7. D.G. Foulke and F.E. Crane, *Electroplaters Process Control Handbook*, Reinhold Publishing, New York, NY, 1963; p. 135, 137, 313-332.
8. J.D. Greenwood, *Hard Chromium Plating*, Robert Draper, Ltd., Teddington, Middlesex, UK, 1964; p. 31-54.
9. F.A. Lowenheim, *Electroplating*, McGraw-Hill, New York, NY, 1978; p. 230-247.
10. D.W. Hardesty, *Plating*, **56**, 705 (1969).
11. A.W. Logozzo, *Plating*, **56**, 1019 (1969).
12. G.T. Sink, *Plating & Surface Finishing*, **63**, 20 (August 1976).
13. R. W. Messler and R. R. Maller, *Plating*, **61**, 758 (1974).
14. A.W. Logozzo, *Metal Finishing Guidebook*, **77**, 188 (1979).
15. M. Inagaki and S. Ueda, *Surface Technology*, **4**, 521 (1976).
16. G.F. Bidmead, *Trans. IMF*, **53**, 126 (August 1975).
17. G. Lausmann, *Metalloberflache*, **29**, 391 (1975).
18. H-R. Kaiser, Doctoral dissertation, T-H Darmstadt, Germany (October 1964).
19. H. Wiegand and U.H. Furstenberg, *Hartver-Chromung, Eigenschaften und Auswirkungen auf den Grundwerkstoff*, Maschinebau Verlag GmbH, Frankfurt, Germany, 1968; p. 126.
20. R.M. Krishnan, *et al.*, *Metal Finishing*, **73**, 50 (1975).
21. J.C. Saiddington and G. R. Hoey, *Plating*, **57**, 1112 (1970).
22. D-T. Chin, *Plating & Surface Finishing*, **64**, 57 (September 1977).
23. P. Hidnert, *Phys. Rev.*, **39**, 186 (1932).
24. H. Schreiner, Doctoral dissertation, T-H Darmstadt, Germany (January 1977).
25. R.D. Bedi, *Plating*, **55**, 238 (1968).
26. A.I. Falicheva, *et al.*, *Protection of Metals*, **12**, 316 (May/June 1976).
27. N. Laing, *et al.*, U.S. Patent 4,092,226 (1978).
28. E.W. Turns and M.E. Browning, *Proc. 49th Annual AES Tech. Conf.*, AESF, Orlando, FL, 1962; p. 53.
29. K.S. Willson, *Plating & Surface Finishing*, **62**, 784 (1975).
30. J.C. Saiddington and G.R. Hoey, *Plating*, **61**, 923 (1974).
31. A.K. Graham, ed., *Electroplating Engineering Handbook*, 3rd ed., Van Nostrand-Reinhold Co., New York, NY, 1971; p. 601-603.

Editor's note: The preceding article is based on an article contributed by Myron E. Browning, CEF, for the "AES Update" series that ran in this journal in the late 1970s and early 1980s. Since this article was written, there has been considerable history added to hard chromium plating technology. Nevertheless, the reader may benefit both from the information that remains relevant and the historical perspective of the technology in 1980. The "Update" series, was begun and coordinated by the late Dr. Donald Swalheim, and brought practical information to the metal finisher. In some cases here, words were altered.