Mechanical Plating and Mechanical Galvanizing

A Brief Introduction

Mechanical plating is an effective means of applying zinc, tin, aluminum, or other ductile metals or mixtures thereof to metal substrates (almost always ferrous articles). It has a number of advantages over conventional plating and coating processes.

The most important reason for mechanical plating is the assurance of product reliability through the ***elimination of hydrogen embrittlement****. Mechanical plating is the method preferred by many engineers for hardened fasteners and stressed components.*

Mechanical deposition processes eliminate lengthy pre-plating and post-plating baking cycles. For reducing the risk of hydrogen embrittlement (the ASTM is quite clear that these cycles do not eliminate the risk of hydrogen embrittlement) ASTM B850-98 (2009) recommends the following baking cycles for heat-treated electroplated articles:

Rockwell Hardness	***Post-Plate Bake @ 400°F.***
31 - 33	*8+ hours*
33 - 36	*10+ hours*
36 - 39	*12+ hours*
39 - 43	*14+ hours*
43 - 45	*16+ hours*
45 - 47	*18+ hours*
47 - 49	*20+ hours*
49 - 51	*22+ hours*

Customers can visually confirm that parts have been mechanically plated - something that cannot be done to confirm baking cycles. Mechanical plating has a matte finish easily distinguishable from the bright finish of electroplating.

The ability to plate parts which tangle; *the glass impact media used in the process tends to prevent parts from tangling. The mechanical plating process characteristically makes this technology an ideal choice for plating hardened steel springs.*

The ability to plate flat parts; *the media prevents flat parts from masking one another, making sure that all surfaces are uniformly plated. This makes mechanical plating an ideal process for plating flat stampings and washers.*

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*Because mechanical plating consumes all of the chemistry in each process cycle, there is **no build-up of contamination in the bath**. This assures users of long-term product and process consistency.*

*Mechanical plating has the ability to **plate sintered metal parts** (powder metallurgy) without costly impregnation.*

The ability to plate zinc or tin or any alloys of zinc and tin. *For this reason, mechanically deposited zinc-tin alloys are used extensively in roofing fasteners, especially in Australasia.*

Attractive economics for coating thicknesses above 0.0003". *This is due primarily to the fact that in mechanical plating the process for thick coatings is only slightly longer than the cycle for thin coatings (unlike electroplating, where the plating time is directly proportional to the plating thickness). The cost of additional plating thickness in mechanical plating is only slightly more than the cost of the plating metal. This is why mechanical galvanizing is used extensively for construction fasteners.*

Mechanical plating offers processes which deposit alloys of zinc and aluminum, *providing fastening systems used on aluminum structures.*

***Mechanical Galvanizing** is an extension of the well-established mechanical plating technology. The process is nearly identical to mechanical plating except that the amount of metal (zinc) deposited is substantially greater - galvanized coatings begin at 1 mil (.045 ounces per square foot) and go up to 1½ ounces per square foot (3.3 mills). Generally, parts to be mechanically galvanized can be up to 1 pound in weight and up to 6 inches in length. Mechanical Galvanizing offers these important features, advantages, and benefits:*

No hydrogen embrittlement. *Because Mechanical Galvanizing is an extension of mechanical plating technology, it does not produce hydrogen embrittlement and does not require lengthy pre-plate or post-plate baking cycles.*

No detempering. *Mechanical Galvanizing is a room temperature process that does not detemper heat-treated parts.*

Excellent thread fit. *Mechanical Galvanizing does not fill the valleys of threaded fasteners. Mechanically Galvanized parts mate quickly and easily.*

No need to chase nuts after plating. *In hot-dip galvanizing, threads must be cut or chased after galvanizing, robbing them of protection and requiring extra expense. Mechanical Galvanizing produces parts that are ready to use without any further processing steps.*

No galling. *Because of the composite nature of mechanical coatings, this naturally lubricious coating will not gall, producing more accurate torque-tension relationships.*

No stickers. *In hot-dip galvanizing, molten zinc often fuses parts together, resulting in lost time, effort, and materials. In contrast, mechanically galvanized parts are 100% usable. This is why millions of washers are mechanically galvanized every year.*

Excellent adhesion. *Because of the underlying coatings, Mechanical Galvanizing has excellent adhesion to the base metal.*

The primary purpose of mechanical plating processes is to enhance the corrosion protection of the parts plated, without introducing hydrogen embrittlement into the part.

Zinc (and other active metals) protect the underlying ferrous substrates by a process called sacrificial protection or cathodic protection. In this method of corrosion protection, the metals that are more active (chemically speaking, with more negative potentials or higher in the electromotive series), such as zinc, protect those that are less active or more noble by "sacrificing" themselves to protect the underlying more noble base metal. As a general rule, the protection offered by zinc is proportional to the coating weight per unit area, regardless of the way in which it is applied. This process works effectively even if the sacrificial metal coating is slightly damaged.

The corrosion protection offered by zinc deposits is dependent upon three factors:

- *Coating thickness*
- *Post-plate treatment(s)*
- *Environmental exposure*

Zinc plating corrodes at rates which are dependent upon the severity of the environment, as shown below. (Source: ASTM B-695-04 (2009)

Atmosphere	***Mean Corrosion Rate***
Industrial	*5.6 micrometers (0.22 mils) per year*
Urban Nonindustrial	*1.5 micrometers (0.06 mils) per year*
Suburban	*1.3 micrometers (0.05 mils) per year*
Rural	*0.8 micrometers (0.03 mils) per year*
Indoors	*considerably less than 0.5 micrometers (0.01 mils) per year*

Because the corrosion protection offered by sacrificial deposits is so lengthy, accelerated tests are routinely used to predict the long-term effectiveness of the deposits. The two most common tests used are the Kesternich Test and the ASTM B-117 Salt Fog (Salt Spray) Test. In this latter test (which is much more common) a fog is generated from a 5% neutral (i.e., a pH of 7) salt (sodium chloride) solution. The parts are then evaluated for the first appearance of white corrosion products ("white rust" or oxides of zinc) and (later in the test) the formation of red rust, or base metal corrosion.

In general, chromates and trivalent passivates will add corrosion protection as follows:

Clear Chromates (Hex)	*12 - 24 hours*
Yellow Chromates (Hex)	*96 - 168 hours*
Olive Drab Chromates (Hex)	*96 - 192 hours*
No Rinse Hyperguard (Hex)	*96 - 192 hours*
Thin film trivalent passivates	*12 - 24 hours; in some cases less.*
Thick film passivates (900 nm)	*96 - 120 hours under optimal processing conditions*

Trivalent passivates function by generating hexavalent chromium during the corrosion process.

Proprietary sealants (such as PS&T's Hyperseal®) can be applied over chromates and trivalent passivates to significantly enhance the protection. The additional protection offered by such products is typically 100 to 200 additional hours. Passivates protect the underlying deposit by delaying the onset of the white corrosion products. Passivating processes are often "conversion coating processes"; in which the articles are dipped into a solution containing chromium salts and acids and the solution "converts" the topmost part of the zinc into a corrosion-inhibiting coating. The application of chromate conversion coatings in their heyday was the most cost-effective corrosion protection available.

The thickness of the zinc deposit and the salt spray protection (to red rust or base metal corrosion) are correlated as follows: (from ASTM B695 and GM4344M and GM4345M)

Zinc Thickness	***Salt Spray Protection***
0.00012 inches (3 micrometers)	*24 hours*
0.00024 inches (6 micrometers)	*48 hours*
0.00035 inches (9 micrometers)	*72 hours*
0.00047 inches (12 micrometers)	*96 hours*
0.00059 inches (15 micrometers)	*120 hours*
0.00098 inches (25 micrometers)	*192 hours*
0.00157 inches (40 micrometers)	*250 hours*
0.00197 inches (50 micrometers)	*300 hours*

How does the Mechanical Plating Process Work?

1. Parts are often cleaned in a hot alkaline soak cleaner, then dipped in an acid pickle, then rinsed.

2. Clean parts which are free from oil and scale are loaded to a rubber-or plastic-lined plating barrel, usually hexagonal in shape. Plating barrels may have capacities as low as 1.5 cubic feet of parts and as high as 40 cubic feet.

3. Parts can also be cleaned in the barrel using one of PS&T's Descaler/Degreasers specifically designed for cleaning parts in the barrel prior to mechanical plating. Some parts may be plated without cleaning, using the cleaning capability of the PS&T Starter chemistry to clean the parts.

4. With the parts, impact media is loaded to the barrel. Impact media is a mixture of varying sizes of spherical glass beads ranging from 4 mesh up to 60 mesh. Normally equal quantities by volume of glass beads and parts are loaded to the barrel, although heavier parts or heavier coatings of more difficult parts require a higher media-to-parts ratio.

5. The water level in the barrel is then adjusted to an appropriate level for the parts to be plated. For most parts, the water level should be approximately 1 to 2 inches ahead of the media/parts/water mix when the barrel is rotating at the proper speed.

6. The temperature of the media/parts/water mix should be 700F. to 800F., although PS&T's processes will operate somewhat outside this range. Lower temperatures result in slower plating; higher temperatures will result in more rapid plating.

7. Next, Starter is added to provide the correct chemical environment for the plating process. PS&T manufactures a variety of different Starters as well as Starter Concentrates, which are used with separately sourced mineral mineral acids.

8. The barrel is allowed to rotate for several minutes, allowing the complete distribution of the Starter into the mix and removing residual oxides from the surface of the articles.

9. Next, a proprietary coppering formula is added to the barrel. In combination with the Starter, this formula produces a tightly adherent copper colored coating on the parts, providing a uniform, predictable base for subsequent mechanical plating. PS&T manufactures a variety of coppering formulas. Usually this step requires from 4 to 8 minutes.

10. Once the coppering step has been completed, a proprietary Promoter chemical is added (PS&T makes a variety of Promoters for specific applications). This compound promotes the plating of the mechanical plating metal.

11. Next, a small quantity of metal is added to the barrel to produce a 'flash' coating that provides a sound base for the subsequent addition of plating metal.

Process (continued)

12. Once the parts have achieved a silvery hue, plating metal is added to the barrel in an appropriate quantity for the surface area of parts in the barrel and the thickness of coating desired. Plating metal is extremely fine dust, 3 to 20 microns in diameter; the much larger size of the impact media 'cold welds' the metal plating powder to the parts. PS&T chemistry provides the correct chemical environment for this mechanical plating process to occur.

13. The most highly advanced mechanical plating technology (HyperflowTM) utilizes a slurry system to deliver the zinc (or zinc-tin) to the plating barrel. This provides a smoother deposit and reduces the part-to-part thickness variation.

14. Normally, the metal to be plated is split into a number of separate additions. Increasing the number of separate additions provides a more uniform coating and reduces the part-to-part variation.

15. pH is monitored carefully by the plating operator during the process. The pH is not allowed to rise above a value of 2.0, since plating ceases above that value.

16. Once all of the metal additions have been made, the operator checks the coating thickness. It is important at this point to plate out the metal powder remaining in the barrel, providing for a more tightly consolidated coating and more efficient utilization of the plating metal.

17. Once the parts have achieved the target plating thickness, they are rinsed and separated from the plating media.

18. After the parts are rinsed, they may be treated with a conventional yellow, olive drab, or clear chromate or with PS&T Brand HyperguardTM, a no-rinse clear chromate. Trivalent passivates such as Hyperguard 326 have largely replaced conventional chromates at a sacrifice in performance and a significant increase in cost.

19. Following the optional application of chromates or trivalent passivates, Hyperseal® may be applied to the surface of the parts. This can significantly extend the corrosion protection of the coating system as the inhibitors in the Hyperseal® function synergistically with the inhibition provided by hexavalent chromium.

History

Mechanical plating was developed by Erith Clayton of The Tainton Co. in Baltimore in the late 1940's and early 1950's. Clayton started a new corporation, Peen Plate, to develop the chemistry required to deposit commercial thicknesses of plating metals. .

History (continued)

Peen Plate, lacking the resources to achieve commercial development of the process, licensed the mechanical plating process to 3M of St. Paul, Minnesota. 3M made significant improvements in the process and achieved significant commercial success.

In 1983, 3M sold the business to MacDermid, Inc. In 1985, Tom Rochester founded Plating Systems and Technologies, Inc., which is now the leading manufacturer of mechanical plating products worldwide.

Specifications

American Association of State Highway and Transportation Officials (AASHTO)
AASHTO M298-87 "Coatings of Zinc Mechanically Deposited on Iron and Steel"

American Society for Testing and Materials (ASTM)
ASTM B695 "Standard Specification for Coatings of Zinc Mechanically Deposited on Iron or Steel"

Caterpillar
1E1675 *"Coating - Fastener*

Chrysler Corporation
PS-Plating "Zinc - Mechanical and Electroplated"
PS-8956 "Conductive Plated Coatings for Electrical Connectors and Corrosion Protection"

Ford
ESF-M1P67-A "Plating, Mechanical - Zinc"

General Motors
GMW3044 "Zinc Plating" and GM4345M/GM4344M "Corrosion Protective Coatings - Zinc Plating"

International Standard
ISO12683 "Mechanically deposited coatings of zinc – Specification and test methods"

John Deere
JDM F22 "Specification for Mechanical Zinc Coating"

Mercury Marine
M-220-P "Mechanically Deposited Coatings"

Nissan
M4066 "Iron Zinc Alloy Mechanical Plating – Silicate Resin Coatings"

Specifications (continued)

Stanley
P-1275 "Mechanical Plating – Aluminum Tin Zinc" and P-1309 "Mechanical Plating – Tin/Zinc"

Tesla Motors
TM-0010F-M "Mechanically Deposited Zinc Anti-Corrosion Coatings"

Toyota
TSH6701G "Mechanical Plating Zinc – Iron – Aluminum Composite Coating"

Volkswagen
TL155 "Ternary Composite Layer for High Strength Fasteners"

United States of America (Replaced by ASTM Specifications)
MIL-C-81562B "Coatings, Cadmium, Tin-Cadmium and Zinc (Mechanically Deposited)"

Equipment (see drawing on Page 9)

The leading manufacturer of mechanical plating and mechanical galvanizing equipment is Dynamic Systems, LLC, in Waukesha, Wisconsin. (www.dyn-sys.net), to whom we are indebted for the following descriptions. Generally speaking, the equipment required for mechanical plating costs about one-quarter to one-third of the cost of an electroplating system of equivalent capacity. The primary components of a mechanical plating or galvanizing system include:

Plating Barrel(s)

The most effective plating barrels are those with a "tulip" design. They are constructed from carbon or (more typically) stainless steel and lined with an acid-resistant and abrasion-resistant lining such as polyurethane (currently the best lining system), neoprene, or polypropylene. The volume of parts that can typically be plated is the generally the same as the volume of media; the volume that can be galvanized (1 mil coatings and above) is typically half of that.

Surge Hopper

This item accepts the load of plated parts and feeds the separator, allowing the operator to begin plating another load while the parts and media are being separated.

Separator

Equipment which separates the parts and the media. Primitive separators are merely a screen with water sprays; more complex separators are ibratory separators and Magnetic Separators (which are the currently preferred process). The final stage is always a fresh water rinse.

Media Handling System
The media handling system returns glass impact media from the sump underneath the separator to an Overhead Media Reservoir. Most platers utilize two loads of media.

Chromator/Passivator (not pictured)
For optimum corrosion protection, a chromate or passivate is applied to the deposit using a spray or dip process. Generally, dipping in baskets gives better results. For threaded fasteners (and some other articles) a wax or lubricant is often applied.

Dryer
The parts may be dried in a "toss-catch" dryer, a belt dryer, or in a centrifugal dryer. Generally, centrifugal dryers are preferred because they use less energy and produce a higher quality product, even though they require a greater labor input.