Mechanical Plating -
The Forté of Plating Systems & Technologies

With the ever-increasing concerns about commodity prices, environmental issues and impending global regulatory regimes, many of the mainstay metal finishing processes have been subject to scrutiny. Some efforts consider whether a popular process can survive all of this inquiry. Others consider the possibility that technology which exists, but may not have been in the forefront for a while, deserves a second look. Mechanical plating is one of those, and the leading supplier of mechanical plating chemistry to job shops, with the largest share of the North American market, is Plating Systems & Technologies (PS&T), Inc., in Jackson, Michigan.

MacDermid Industrial Solutions Division, in Waterbury, CT and Atotech USA, in Rock Hill, SC are also significant suppliers to this market on a worldwide basis.

Plating Systems and Technologies, Inc. was founded in 1985 to serve the market for mechanical plating and mechanical galvanizing. Tom Rochester, Founder, Chairman and Chief Technology Officer of PS&T, worked at 3M with responsibility for manufacturing and developing new products. 3M's Plating Systems Department was sold to MacDermid, and he briefly worked for them before founding PS&T. David Rochester, President of PS&T, is a graduate of the University of Rochester and obtained his CEF in 2000. He was PS&T's first employee in 1986 and has been involved full-time since 1996.

Mechanical plating is a departure from the more familiar methods of depositing a metal. Instead of using electrical energy to deposit a metal as in electroplating, or chemical energy as in electroless or immersion plating, a mechanically-plated coating uses mechanical energy, literally pounding the coating onto the substrate.

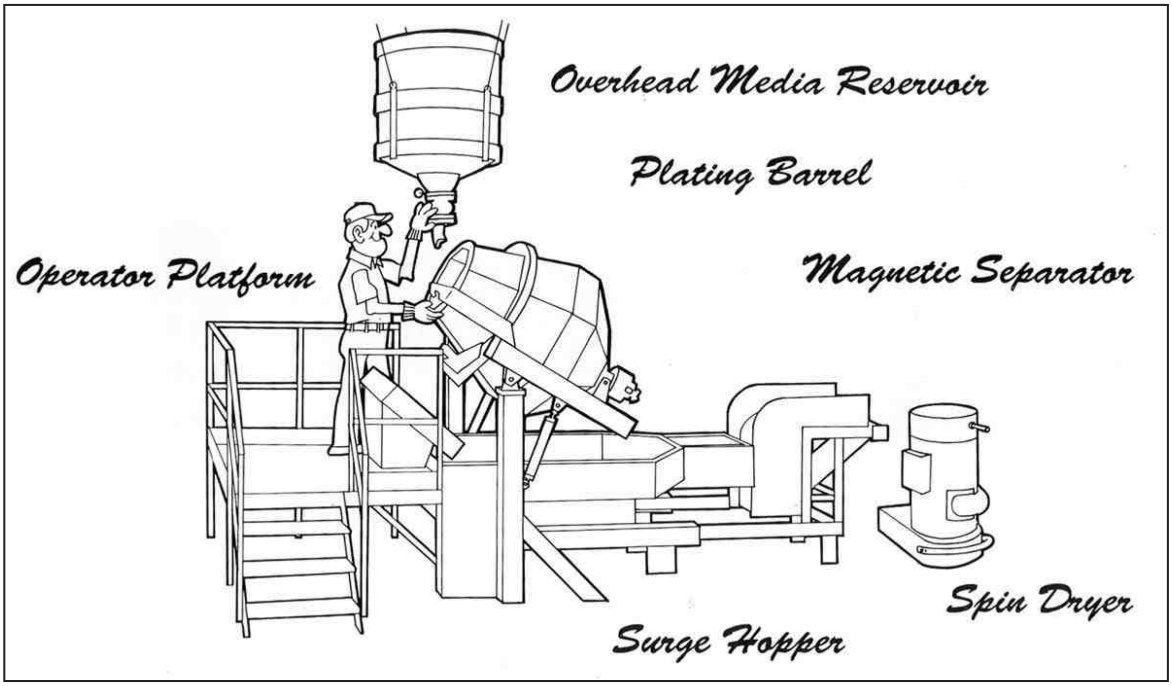
Anyone who has been caught in a hailstorm, or has left their car parked out in one, can attest to the power of mechanical energy on surfaces, whether the surface is a car roof, or one's own head. More to the point, the whole field of mechanical finishing, including abrasive blasting, shot peening, vibratory finishing, etc., relies on mechanical energy to impart a desired surface finish on an article.

Originally developed in the 1950s, mechanical plating is another means of depositing ductile metals - zinc, tin, copper, gold, silver, indium, cadmium, lead and alloys/mixtures thereof - onto substrate metals, particularly steel. Done in a rotating barrel, the parts to be plated are immersed in a water slurry containing:

- the coating metal in the form of fine particles, 3 to 20 μm in size,
- spherical glass beads to do the mechanical work, with mesh sizes from 4 up to 100 (4 mesh is approximately ¼"; 100 mesh is about 1/100 inch in diameter),
- proprietary chemicals, which inhibit oxidation of the particle and substrate surfaces so coatings will adhere to the substrate and to one another.

The rotating barrel produces a tumbling action, physically similar to the motion encountered in an electroplating barrel, but of course there is no need for a dangler to conduct electricity. The mechanical energy produced by the rotation is transmitted through the beads, which impact the parts in the barrel. This impact energy results in the cold-welding of the metal powder particles to the substrate, and to each other. In the process, the particles coalesce and an adherent, coherent coating is formed on the substrate.

The history goes back to the middle of the 20th century. Mechanical plating was developed by Erith Clayton of The Tainton Co., Baltimore, Maryland, in the late 1940s and early 1950s. The Tainton Co. was involved in producing flaked metals from metal powders. In this process, metal powders were tumbled with



Typical mechanical plating installation.

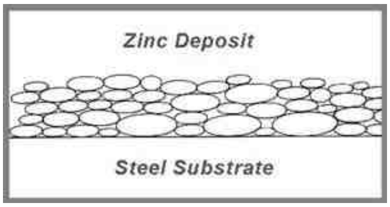
steel balls to produce a powder comprised of thin, shiny particles. Clayton noticed that the steel balls used in the process did not rust, and hypothesized that this was the result of some of the metal powders being plated onto the steel balls. Clayton felt that modifications of the chemistry could provide a process for depositing metal on metal without the use of electricity.

Clayton started a new corporation, Peen Plate, to develop the chemistry required to deposit commercial thicknesses of plating metals. After numerous experiments, a process was developed in which parts were tumbled with steel shot and zinc dust, along with chemicals that Clayton had developed. The tumbling process generally took at least several hours and often over eight hours to achieve the thicknesses required. The steel shot required acid stripping after each run.

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, reducing the cycle time to approximately 90 minutes per run. One of the most important improvements made by 3M was the use of glass beads as the impact media instead of steel shot, an invention which is at the foundation of mechanical plating today. This was a useful link between 3M's position in mechanical plating and their position as a developer of retroreflective glass beads for safety purposes (as in highway signs).

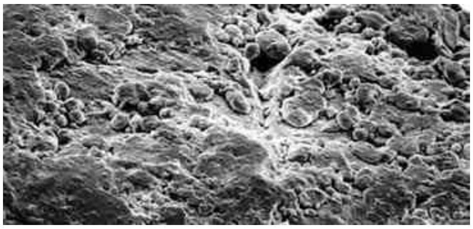
Tom Rochester notes that the technology can be divided into two clear-cut segments - mechanical plating and mechanical galvanizing. In a broad sense, the division is somewhat analogous to the difference between decorative and hard chromium. Mechanical plating covers coating thicknesses that would be typical of fastener finishes, in the range of 0.1 to 0.3 mil (3 to 8 μm), in the case of zinc. Mechanical galvanizing is actually an extension of mechanical plating. By the term "galvanizing," it involves zinc, but the amount of metal deposited is substantially greater. Galvanized coatings range from 1.0 to 3.3 mils (25.4 to 83.8 μm; 0.56 to 1.85 oz/ft^2). Generally, mechanically galvanized parts can range up to one pound in weight and six inches in length.

Mechanical plating has a number of advantages over conventional plating and coating processes. The most important consideration is the virtual elimination of hydrogen embrittlement. Indeed, some hydrogen is generated during the cleaning and pickling cycles, but by far the most significant source of hydrogen embrittlement in electroplating is cathodic inefficiency, which is followed by sealing the hydrogen within the parts.



Coating porosity

While it is true that mechanical plating uses inhibited acids which generate less hydrogen, PS&T believes that mechanical plating as a process is inherently free from hydrogen embrittlement because the deposit is porous (as are phosphate coatings), allowing hydrogen to escape through the coating. With electroplating, by contrast, hydrogen is sealed in the part. As a result, mechanical plating is the method preferred by many engineers for hardened fasteners and stressed components.

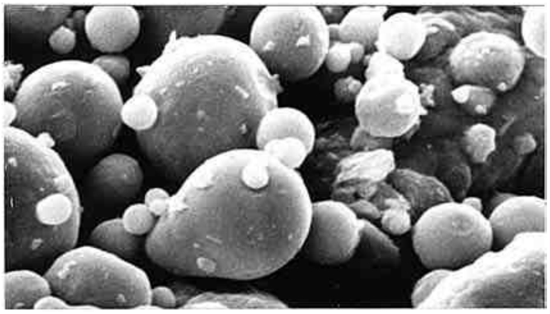


Surface morphology of mechanically-plated zinc (SEM, 600X)

Consequently, mechanically-plated articles offer the elimination of lengthy pre- and post-plating baking cycles. For extremely hard parts, baking cycles can be quite extensive - in some cases, as long as 40 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 a bright electroplated finish.

Glass beads (Original magnification, 25X)

The media, in the form of spherical glass beads offers some advantages as to how the parts move in the barrel. The glass impact media tends to prevent parts from nesting, as there is a tendency for the parts to "roll" off one another. The barrel design is specifically shaped to provide the maximum energy transfer from the media to form the coating. It is actually possible to mechanically-plate hardened steel springs. Similarly, the media prevents flat parts from masking one another.



Electron photomicrograph of zinc dust (Original magnification, 7,150X)

The metal powders used in this process are critical to efficient and effective mechanical plating. These metal powders are produced by a distillation process in which the metal is vaporized and then condensed as a fine powder. Because the powders are produced by distillation, they are quite pure. Zinc dust typically has an average size of 5 to 8 microns and usually 99.75% or more passes a 325 mesh screen.

Mechanical plating is unique in that it consumes all the chemistry in each process cycle, and thus there is no build-up of contamination in the bath. Plating thickness is controlled completely by the amount of metal powder added to the bath. This also requires that the surface area of a given load of parts be precisely known. To that end, for fasteners, Mr. Rochester has developed surface data for a comprehensive range of thread configurations.

Indeed, mechanical plating is particularly advantageous in handling threaded fasteners. Using the proper choice of glass bead sizes to fit the thread configuration, a uniform thickness is achievable over a variety of thread profiles.

The basic process itself is rather simple, and quite reliable. The mechanical plating process, as PS&T describes it, is conducted as follows.

Parts are typically cleaned in a hot alkaline soak cleaner, then dipped in an acid pickle and rinsed. The cleaned parts, free from oil and scale, are loaded into an oblique rubber- or plastic-lined plating barrel, usually hexagonal in shape. This should not be confused with an electroplating barrel, as there are no perforations in it. It acts as the reaction vessel for the entire process. Mechanical plating barrels may have capacities as low as 1.5 ft^3 of parts and as high as 40 ft^3.

Alternatively, parts can also be cleaned in the barrel itself, using one of PS&T's proprietary descaler/degreasers specifically designed this purpose. Some parts may be plated without separate cleaning, using the cleaning capability of the PS&T starter chemistry to clean the parts.

Barrel operation

After determining the size of the part load, and determining the amount of powder, the size and amount of glass impact beads and the amount of chemicals required for the job, the parts, along with the beads (but not the metal powder), are loaded into the barrel. Normally, equal volume quantities of glass beads and parts are used, although heavier parts or heavier coatings of more difficult parts require a higher media-to-parts ratio.

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. The temperature of the mix should be from 70°F to 80°F. Lower temperatures result in slower plating; higher temperatures will result in more rapid plating.

Next, the proprietary starter chemicals are added to provide the correct chemical environment for the plating process. As noted above, these can promote cleaning action in some cases. The barrel is allowed to rotate for approximately two minutes, allowing the complete distribution of the starter into the mix. The barrel continues to rotate until the surface of the parts is completely clean. While this usually takes a few minutes, if the parts are exceptionally dirty, it can take much longer.

Next, a proprietary coppering formula is added to the barrel. In combination with the starter, a tightly adherent copper colored coating is deposited on the parts, providing a uniform, predictable base for subsequent mechanical plating. This step usually requires from 4 to 8 minutes. Once the coppering step has been completed, a proprietary promoter chemical is added, which promotes the plating of the mechanical plating metal.

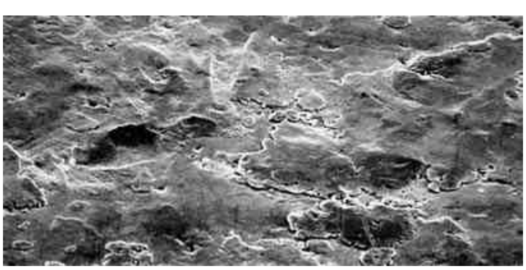
Close up of process in the barrel.

A small quantity of metal is added to the barrel to produce a "flash" coating to provide a sound base for the subsequent addition of plating metal. Once the parts have achieved a silvery hue, the 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. 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.

The pH is carefully monitored during the process, and should not be allowed to exceed a value of 2.0, since plating ceases above that value.

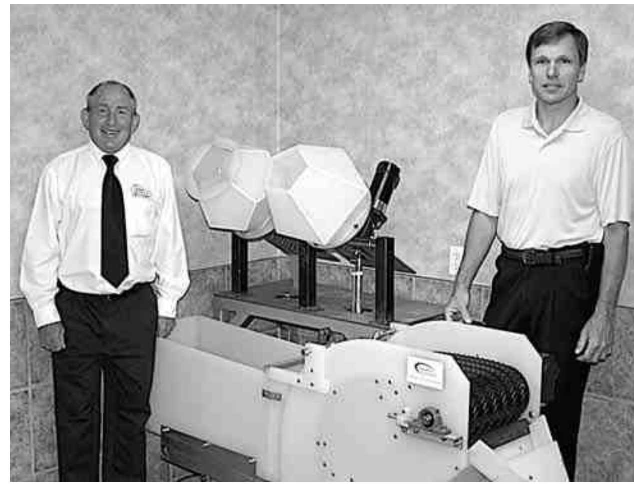
Once all of the metal additions have been made, the operator checks the coating thickness. At this point, it is important to plate out the remaining metal powder, to provide for a more tightly consolidated coating and more efficient utilization of the plating metal. Once the parts have been coated with the target plating thickness, they are rinsed and separated from the plating media. In the case of a steel substrate, magnetic separation is used. After rinsing, normal post-plate treatments can be applied.

In Jackson, Michigan, the PS&T facility mixes and blends the proprietary chemicals and buys and sells the glass beads and metal powders for the full process. PS&T has cooperative arrangements with Dynamic Systems, LLC, of Waukesha, Wisconsin, who builds equipment for mechanical plating and galvanizing.



Surface morphology of Hyperflow® mechanically-plated zinc (SEM, 600X)

Over the years, PS&T has further developed and improved the mechanical plating process. One important enhancement is the Hyperflow® process, which has resulted in a significant improvement in producing a smoother surface finish. Here new proprietary chemistry has been developed to reduce any tendency for the metal powders to agglomerate. The result is a considerably smoother surface when compared to the surface of the conventional mechanical plated deposit seen earlier in this article.



Tom Rochester, Chairman and CTO of PS&T (L) and John Kobe, President of Dynamic Systems (R) show the new pilot-scale laboratory system for mechanical plating.

A new laboratory has recently been completed at PS&T's Jackson facility, which affords the customer access to real world tryouts, on a small, production scale. It will also afford the opportunity to improve the productivity of the process and develop and refine testing procedures. Efforts will be concentrated on the issues of the day, including leveraging the advantages of mechanical plating into the ELV and RoHS regulatory environment. It is also intriguing to contemplate the possibility of using nano-scale metal powders.

As is common in the surface finishing industry, the increasing number of possible finishes and processes has fragmented the industry, with a multiplicity of finish alternatives. Yet, taking a second look at mechanical plating may offer a promising future for it in meeting the challenges of the coming years. *P&SF*