Electropolishing: Process Considerations

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Electropolishing has been in commercial use since the 1950s. It continues to be a very popular surface finishing process, geared to achieving specific surface treatments on a wide variety of metals. The net result is the application of electropolishing in many industries, none of which would be able to function optimally without the benefits that electropolishing affords. Let's break down the process and highlight important aspects.

Basically, electropolishing replaces traditional mechanical treatments, such as milling, blasting, grinding and polishing. These often labor intensive operations can be substituted by the economical and expedient electropolishing treatment. This is an excellent procedure to streamline and smooth microscopic surfaces. Polishing and deburring are accomplished in a single step. Burrs, typically less than 0.005 in. in size, are removed. It allows for greater bulk processing of parts. What you get is a clean, even surface finish. It is one of the best surface polishing methods. Sterilization is enhanced for medical and pharmaceutical applications. Passivation of stainless steels to optimize corrosion resistance is excellent. Other exceptional results include:

- Removal of oxides and tarnish
- Producing a uniform surface (aesthetic appearance)
- Reducing friction and galling
- Producing a desired microhardness
- Increasing magnetism
- Improving welding and brazing.

There is a wide range of industries that make important use of electropolishing. These include: general fabrication, marine, aerospace, automotive, pharmaceutical and medical, petrochemical, food and beverage service, furniture and appliances. Over the years different electrolytes have been developed that can electropolish many metals and alloys, including stainless steels (300 & 400 series), aluminum, brass, copper, bronze, nickel, steel, titanium, Inconel®, Hastelloy®, gold, silver and Kovar®,

How it works

Electropolishing follows the fundamental principles of Faraday's Law. It is an anodic treatment of parts that are fully immersed in a special acidic electrolyte. Ancillary equipment, such as bussing, heaters, anode and cathode bars, DC rectifiers and agitation, are all similar to those used in traditional electroplating. With current applied at specific current densities, for a pre-determined time, anodic oxidation dissolves metal off the substrate surface. It is essentially a controlled, accelerated corrosion of the part. Optimum electropolishing is achieved per the traditional operating parameters (current, time, temperature), along with bath chemistry, racking, positioning and part-to-cathode (instead of anode, in plating) distance.

The bath is a mixture of acids, such as sulfuric and phosphoric, along with other agents, saturated with dissolved metal salts. A chemical equilibrium forms, with precipitated metals as sludge. The sludge is periodically decanted and some of the electrolyte replaced, to maintain a specific solution specific gravity. The operating solution specific gravity increases with the accumulation of ampere hours. It becomes thicker, taking on the properties of an insulator or resistor. With applied current and focusing on the direct surface-to-immediate solution interface, the solution film thickness increases, thereby insulating the high current density areas of the part surface. This section of the part becomes less active. In the low current density areas, the solution film thickness decreases, resulting in a less insulated, or more active portion of the part. This comparison of surface activities leads to a normalization of microscopic peaks and valleys, dramatically improving the surface leveling characteristics.

Other benefits occur during the electropolishing treatment. Hydrogen is removed from the surface of parts, providing the equivalent of a stress relief anneal. Oxygen evolves at the part (anode), forming an agitation medium. This refreshes the electrolyte film surrounding the part. Electrical charges are greatest at the edges, or sharpened, irregular points. That is why electropolishing is an excellent deburring application. These areas exhibit greater electromotive potential. In the opposite picture, valleys or low current density areas exhibit less electromotive potential. This electromotive potential controls the electropolishing dynamics.

There is a significant preference to remove high spots on the surface, resulting in a dramatic change of dimensions to high spots. Conversely, there is less change to the dimension of low spots. The result is an overall smoothening effect to the metal surface. Compared to mechanical treatments, the dimensional change in electropolishing is small to obtain the desired polishing effect. The overall dimensional change to a part can be 0.00025 in.

A general rule is that large flat surfaces tend to produce satin or refractive finishes. Smaller parts or those with a radius of curvature tend to produce reflective, mirror finishes. The more curve to surface results in a brighter polishing effect.

Processing terms

The following are some terms relevant to electropolishing and post evaluation of the surface of conditioned parts.

- *Surface Roughness*. R_a (roughness average) or RMS (root mean square) is measured in microinches. It is a quantitative measure of the smoothness of the finished surfaces.
- *Surface Chemical Analysis*. A determination of contaminant levels or the effect of decontamination, resulting in desired surface purity.
- *Surface Chromium Enrichment*. For passivation, where the chromium concentration exceeds iron, as a ratio in the surface layer. For corrosion improvement.

Next month's column will address process limitations, operating parameters, cycles, control, analysis, maintenance and troubleshooting. *P&SF*