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Electroless Nickel - An Engineered Coating

About the Process

The steadily increasing use of electroless nickel plating can be attributed to marked improvements in solution stability, pretreatment cycles, reducing agents and the equipment used.

One of the major characteristics making its use more prevalent is the ability of the process to provide uniform thickness deposits in deep recesses, bores and blind holes. Other characteristics are: excellent corrosion, wear and abrasion resistance, ductility, lubricity, solderability, electrical conductivity and hardness.

Applications

The alloy can be deposited onto a wide range of substrates. These include carbon, stainless and high alloy steels, iron, aluminum, copper, brass, bronze, beryllium, and such nonconductive materials as plastics and epoxies, among others.

Electroless nickel coatings provide protection from oxidation, corrosion and wear on parts used in air compressors, missile fuel injector plates, pumps and reciprocating surfaces of many types. Used on aluminum electronic devices it not only prevents contamination but also improves the solderability of the surfaces to which it is applied.

Other typical uses are on aerospace hardware, automotive parts, food processing equipment, fluid power components, textile machinery, hydraulics, valves, pumps, plastic molds, electronic components, chemical processing equipment, and printed circuit boards. These are a small representation of the wide range of applications for which electroless nickel is well suited.

How It Is Done

"Electroless Nickel" is a generic term describing the deposition of an alloy composed principally of nickel and phosphorous. Deposition of the alloy is achieved by chemical reduction. The process is nonelectrolytic. Reduction of the nickel alloy occurs during immersion of an activated surface into a hot aqueous solution.

Major Benefits

- Uniformity (Control of deposit thickness +/-.0001"/side is possible)
- Excellent corrosion resistance
- Wear and abrasion resistance
- Non-magnetic and magnetic properties
- Solderability

- High hardness
- Amorphous (microcrystalline) deposition
- Excellent adhesion
- Low coefficient of friction (high lubricity)
- High reflectivity
- EMI/RFI shielding
- Ideal preplate, for precious metal coatings
- Heavy, controlled thickness possible
- Can be applied to a wide range of metallic and non-metallic materials.

The engineering decision to use electroless nickel may come from any one of the combination of benefits it provides.

Physical Properties

Composition: 88-94% nickel, 6-12% phosphorous

Specific Gravity: 7.9

Melting Point: 1635F (890C)

Adhesion to Steel: 30,000-60,000 psi

Hardness, as deposited: 500-600 Vickers (49 Rockwell C)

Maximum Hardness, heat treated: 1000-1100 Vickers (70 Rockwell C)

Elongation: 2-6% permanent strain

Electrical Resistance, as deposited: 60-75 microhms/cm/cm

Thermal Conductivity: 0.01 cal/cm sec C

Coefficient of Thermal Expansion: 7.22 10.6 in./in./F 13.0 106 cm/cm/C

Internal Stress: 15,000 to 40, 000 psi--10.8 to 28 kgmmS

Applied Thickness

Normal thickness applied range from .0001" to .005" per side. Within this range the base substrate will gain the characteristics of the alloy coating for the majority of applications. Part value, surface finish and end functional use are some of the factors determining suitable thickness. Properly applied, the coating may be shotpeened, grit blasted, ground and machined, without flaking, on thickness up to .025" or more.

Uniformity

The coating is extremely uniform and accurate regardless of part geometry. Thickness can be controlled to within +/-.0001" per side. A hydraulic shaft plated in electroless nickel offers many advantages over one plated with hard chromium. The advantages and savings include the elimination of any need to go through a grinding operation after plating. This minimizes the risk of excessive handling. Electroless nickel can be added and controlled to the required finished dimensions. This provides a finished part with a hard, wear-resistant, pore-free deposit and excellent lubricity: all very highly desirable characteristics for this type of part.

A Look At Chrome

By comparison, chromium is electrolytically deposited. The designation "hard chrome" indicates a fairly heavy deposit, as opposed to decorative chrome, which incorporates an underlayer of electrolytic nickel. Hard chrome has been a standard wear resistant coating used by industry in a variety of applications. Its chief advantages are hardness, low coefficient of friction, and adaptability to coating many different metallic substrates, and its availability. The major disadvantage of the hard chrome process is the difficulty presented when trying to uniformly envelop an irregular geometric surface. It also has the least efficient bath of any electroplating process and usually requires the use of expensive conforming anodes to effect reasonably uniform coverage. Conforming anodes mirror-image the surfaces to be plated. Also, in order to "throw" the chromium into recesses, high voltages are necessary and these cause excessive and rough buildup on any surface protrusions.

Masking

With all metallic coating processes, masking can be used to prevent deposition on surfaces where coatings are not needed. Since masking is labor intensive it is advisable to consider the practicality of coating the entire part. This often costs less than adding the expense of masking to the plating operation.

Hardness

Keep in mind that the coating applied by the process is an alloy of nickel (88-94%) and phosphorous (8.2%). The phosphorous content imparts a very low coefficient of friction. Therefore the treated surface becomes similar in many ways to wet a bar of soap. The alloy's metallurgical structure is amorphous, possessing no grain structure, and is very dense.

The hardness of as-deposited nickel (46-49 Rc) can be increased (see chart) by a post-bake cycle varying from 550-750F, depending on the final hardness desired. Obviously the substrate must be able to withstand these temperatures so as not to become distorted. What occurs during the post-bake is the uniform precipitation of nickel phosphide within the matrix of the alloy. This dispersion is carbide-like hard, raising hardness values of the coated surfaces to a maximum of 67-70 Rc.

Corrosion Resistance

The uniformity, structure, metallurgical composition and low porosity of an electroless nickel alloy all contribute to its excellent corrosion resistance to most organic liquids, weak acids and alkalis. Fluorine, chlorine, bromine, iodine, dry ammonia gas, neutral or alkaline aqueous salt solutions, and organics such as hydrocarbons and ketones do not attack the alloy. These are a few of the corrosives the alloy can withstand. Keep in mind that corrosion resistance is a function of surface finish and substrate porosity. Electroless nickel's high resistance to corrosion protects highly polished die surfaces, food machinery, valves and pumps -making them more resistant to their respective environments.

For a plastic mold which has been coated, the vapors produced by molding operations for PVC plastics are aggressive and would cause considerable damage to an untreated die surface. Electroless nickel provides a barrier to the chemical attack of the molding environment. The service life of petroleum industry equipment has been improved through coating of such components as ball and gate valves, nozzles and drilling parts. Electroless nickel has proven to withstand atmospheres of salt water, hydrogen sulfide and other industry related corrosive elements. Such performance will further expand its use to pipelines for both marine and non-marine applications.

Impellers, for example, must withstand abrasion as well as corrosion. Electroless Nickel stands up to environments such as chlorides, sulfides, salt water and sand.

Included in petro/chem applications are rod pumps, packers, mud pumps, collars, couplings, safety valves, fire tubes, extruders and blenders, tanks and vessels. The anti-galling properties of the coating are also of great importance for chemical process equipment.

Electronics Parts

One of the largest growth areas for electroless nickel has been in the electronics field. This is because the deposit is pore-free, uniform, corrosion resistant and solderable. It actually improves the solderability of aluminum and other metals which do not solder well in their natural state. Typical uses are on heat sinks, transistor cans, chassis, connectors, EMI/ RFI shields, radar, circuit boards, and header assemblies, all of which use the coating as a standard finish. Other parts include aluminum computer memory disks, disk heads, paper feed rolls, trays and hub assemblies. It is also being used to replace gold and silver in micro-electronic packaging and device manufacture, as well as an underlay coating for subsequent gold or silver plating. The savings through reduction in precious metal usage is significant. Other applications, appropriate because of corrosion resistance and solderability, are diode cans, rotor cups and connector pins.

Foundry Uses

Molding operations tend to approximate a combination of sand blasting and grinding motion as the mold sand is compacted. Surface hardness imparted by the coating is important. So, too, is the low coefficient of friction which improves wear resistance by allowing easier flow of the molding media over pattern surfaces.

Wear resistance is extremely important on tooling used for close tolerance castings. The tooling used is costly to begin with. Mold repair and replacement costs are also higher. High-pressure molding machines aggravate the wear problem. The preservation of tooling integrity and reduction of mold scrap is enhanced by the use of electroless nickel.

The coating also provides another important benefit by acting as a built-in wear indicator. As it inevitably becomes sacrificed to the molding media, an easily seen change is apparent as the coating wears. A simple, low-cost remedy is available to restore a mold or pattern to its original close-tolerance condition.

The worn coating is removed and replaced. Major repair is minimized or eliminated and tooling detail can thus be preserved indefinitely.

Unlike untreated molding surfaces, to which carbonized molding resins and release agents stick and build up, coated surfaces resist wear due to sand abrasion and provide excellent mold release characteristics.

Food Processing

The food processing industry relies on electroless nickel coatings for many reasons. Originally, its use was promoted to permit low cost metals to be used as a replacement for stainless steel and this continues to be a very cost effective alternative.

Caustic rinsing and cleaning of food materials and equipment is an essential factor to be considered. How well electroless nickel acts as a barrier can be seen by the low annual rate of attack by food processing compounds.

Corrosion of less than 0.1 mils per year is inflicted by: beer, beet sugar liquor, boric acid, calcium chloride, cane sugar liquor, citric acid, detergent, fruit juices in general, lemon juice, milk, peanut and vegetable oils, soap wash liquor, sodium hydroxide, steam, sugar liquor, and distilled water. An attack rate on the order of only 0.5 mils per year is experienced from borax, wet chlorine, sodium bicarbonate and vinegar.

Not only is corrosion and abrasion resistance provided but cleaning of meat processing extruders and dough kneaders is made easier.

Among the food industry applications are food processing rolls, gears, pillow blocks, tables, main frames, slicers, packaging equipment, cookie, cracker and dog biscuit rolls.

Keep in mind that equipment and its component parts used in a food and/or drug environment must meet all USDA and FDA standards. Electroless nickel properly applied does.

Aerospace Uses

Electroless nickel coated parts are used in the U.S.A.F. BI-B and the Space Shuttles.

The coatings have been used for many years on engine parts, turbine and compressor blades, rings, landing gear and ground support equipment. Matching the rapid growth of the new aerospace program during the 60's and 70's was the number of new ways the coating was utilized. Metal optics, guidance, and communication mirrors were a few.

The docking, cargo bay and rear rudder mechanisms of the Space Shuttle and BI-B are coated. The outer support bearing of the Allison TF41 jet engine is subject to abrasion, fretting and temperatures of 9000 F under heavy bearing loads. Electroless nickel has effectively extended the service life of this part. Environmental conditions impacting on the cooling turbine of jet engines calls for use of the coating on the outer plenum, internal outlet and fan and turbine seals. Fuel control cam assemblies and bellows of jet engines require the coating's high abrasion resistance. Because of intricate size configurations and coating requirements, rebuilding worn surfaces of parts is more economical with electroless than with chrome.

The military specifications which must currently be adhered to for this type of work are: MIL-C-26704B; AMS-2404B; AMS-2405A and MILSTD-1.7.1, Finish 1.4.3.1.

Automotive Uses

Automotive uses have grown dramatically in recent years due to the need for lower costs, reduced weights, and parts exhibiting corrosion and wear resistance. The list of engine, power train and exhaust system parts on which the coating is applied grows steadily. Methanol and ethanol, both widely used gasoline additives, plus alcohol fuels produced new corrosion problems for auto manufacturers. Corrosion affecting die cast zinc carburetors and fuel pumps were taken care of by using the coating.

Use Of Composites

The co-deposition of other materials with electroless nickel provides enhanced wear, abrasion resistance and/or lubricity of the surface of base substrates. Among the composites codeposited are those containing fluoropolymers (PTFE), natural and synthetic (polycrystalline) diamonds, ceramics, chromium carbide, silicon carbide and aluminum oxide. Codeposition is employed on components for rubber and plastic molds, fasteners, precision instrument parts, drills, gauge blocks, tape recording heads, guides for computers and food processing equipment.

Conclusion

Electroless nickel plating shows continuous growth in both technology and types of application. Specialists in the field serve the needs of virtually every industry by providing a proven engineering coating capable of withstanding diverse environments. Engineers considering its use should convey all essential data to the companies they are considering as coating suppliers. Information essential to successful use of electroless nickel includes: the application for which it is intended, the intended environment, the results expected or desired, the type of alloy, prints showing critical dimensions and tolerances, and plating thickness required. Desired results can best be achieved through mutual understanding, communication and cooperation.

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