Space-Spawned "Synergistic" Coatings Come "Down to Earth," Then Return to Space for Hubble Repair

Challenges in space and on the factory floor

Whether in the harshness of Space or on the factory floors across the globe, high-tech surface enhancement treatments such as those developed and applied by Linden (NJ)-based General Magnaplate Corporation, transform low-performance, plentiful, and inexpensive metals into harder than steel, "synergistic" coatings. These corrosion-resistant, chemical-resistant, super-hard or dry-lubricated products are helping to meet the increasingly stringent performance demands placed on metals by manufacturers everywhere.

In today’s ever-changing world, the latest state of the art design is immediately challenged by someone else’s innovations. New products must last longer, perform faster, and be more cost-efficient. To accomplish this, design engineers are making great strides in product performance through the use of Magnaplate’s “Surface Enhancement Coatings.” This is the story of one company’s role in the evolution of high-tech surface enhancement coatings — starting with the rigors of Space exploration, moving on to industrial applications here on earth, and then returning to space to meet the challenges of NASA’s newest mission.

Pioneering “Synergistic” Coatings

In the 1950s and 1960s, Magnaplate pioneered the development of “synergistic” surface enhancement coatings for the broad spectrum of metals used originally in America’s space program. A select few of the hundreds of NASA applications for which this company has developed coatings are: cameras, telemetry equipment, drills, fuel valves, soil samplers, landing struts, protective shrouds, seat tracks, frames, doors and windows, latches and hinges, lunar surface drills, space suit and EVA components, the moon vehicle, and toilets.

When it comes to hardening and dry-lubricating metal surfaces, no challenge can match that of preparing a metal to perform in Space. Most conventional protective coatings and lubricants, which on Earth can improve performance and provide protection against friction and wear, would “out gas” or possibly even spark in the vacuum of outer Space. Surfaces would be unprotected.

It should not be a surprise, then, to learn that General Magnaplate has coated thousands of parts on every NASA Space vehicle since the inception of the national space agency. As a result, a wide variety of ferrous and non-ferrous metals have been able to perform tasks that have been, literally, out of this world.

Today, these coatings are used not only in space, but for such “down-to-earth” applications as the prevention of abrasion, erosion and galvanic corrosion of plastic molds; to increase the efficiency of the huge boring machines used in digging the England/France “Chunnel,” the permanent lubrication and hardening of aluminum guide surfaces in high-speed machinery and robotics systems; the solder-spatter-rejection on double wall copper tubing machines; and a host of other applications.

Coatings With A Difference

These “synergistic” coatings are applied to metals in multi-step systems that start with a series of specialized cleaning treatments. The surface of the substrate is then en-
hanced by conversion, deposition, thermal spray, or a blend-matrix of all three—depending on the coating. The process continues with a controlled infusion of engineered polymers or other dry-lubricating particles and/or metals. Unlike painted-on coatings, these particles are mechanically bonded and become a permanent, integral part of the new surface layer. They won't chip, flake, peel, or rub off.

Because these coatings create metal surfaces that are superior in performance to both the base metal and to the individual components of the coating, the Magnaplate treatments are said to be “synergistic.”

Down-to-Earth Surface Enhancement Challenges

Many of the adverse conditions of Space on which the scientists of Magnaplate “cut their teeth” can cause problems which are similar to the down-to-earth corrosion, wear and lubricity problems that this company helps earthbound manufacturers overcome. The challenges can be equally as daunting, as the examples cited below indicate.

Aluminum Computer Heat Sinks

A very tough challenge was posed by the design engineers of one of the world’s leading computer manufacturers. Its specifications for the computer’s aluminum heat sinks called for a surface that is electrically insulative yet also thermally conductive—conditions that would appear to be mutually exclusive. And that was just the beginning of the challenge. The metal components of the heat sinks featured complex configurations which had to be coated but still had to maintain critical dimensional tolerances.

Conventional Anodizing Failed

Standard anodizing techniques failed to meet these unique requirements. Other conventional metal treatments and existing coating technologies also failed to solve one or more aspects of the seemingly conflicting goals established by the computer maker.

When Magnaplate’s engineers first set to work, they quickly determined that a good conventional hardcoat could solve the insulation portion of the problem. However, because of the geometric configuration of this particular heat sink, the thermal conductivity requirement demanded a development program all its own.

The program helped determine that when the initial anodize film first forms, the aluminum is quickly converted to Al2O3. This creates a sharp intermediary boundary consisting of two layers of material. As a result, there is no continuity of the substrate material and thermal conductivity suffers.

Magnaplate realized that it was important to determine the thermal effects of changes in current density and ramping mode. But year-long tests yielded no significant improvements in heat transfer properties. Accordingly a new anodizing electrolyte and an entirely new approach to the problem were developed.

Studies of electrolyte temperatures led to a solution. Tests revealed that it was possible to optimize the coating quality and consistency properties only at a very narrow range of electrolyte temperatures (+/-0.5°F). Operation within this range ultimately yielded consistent and equal thermal dissipation. Cross-sectioning of coupons confirmed this.

Continuing testing and ramping experiments of the finalized chemistry of the newly developed electrolyte generated data indicating positive results. In an effort to discern the degree of penetration (so that it could be more easily seen and identified), and to improve the accuracy of the measurements, a black dye was sealed into the anodic film. Now the grain boundaries and penetration could be better defined when cross-sectioned. Under standard conditions, both the penetration of Al2O3 into the aluminum substrate and the aluminum oxide’s growth approximated 50%. Using the new electrolyte and anodizing process, the degree of penetration into the base metal now became 75%. This achievement is considered a real breakthrough since there appears to be no prior evidence in anodizing literature of such deep penetration of the metal.
New Equipment Created

To achieve this penetration, a specially designed anodizing module was developed. This new module incorporates an anodizing tank, low ripple rectification, two microprocessors with digital gages, and a chart recorder — all insuring repeatability. One of the microprocessors programs the rectification schedule, amps, and time of ramping. A second governs the critical temperature and the temperature controller; the latter is capable of holding ±0.050°. The chart recorder prints out the amperage to record how it changes during the cycle. All these electronics were developed and customized in the module by Magnaplate’s engineers.

In order to achieve the critical uniformity of a coating that would meet the required specifications (0.0005"±0.000050"), the rack design, too, had to be custom-engineered. Careful provisions were made to monitor the current density gradient during the electrolysis of the metal part being tested. It was determined that the most critical contacts to the substrate were at the lowest current density point; contacts could then taper off in the direction of the higher current density points (tips and edge), with no contacts at all at the point of highest density.

It was also determined that the ratio of part surface to tank surface, as well as the efficacy of solution agitation, were also extremely important in maintaining overall coating uniformity.

A New Coating Process

The result of this research was a new anodizing process which is used to create Magnaplate THHC™ coating. In the process, purified and filtered air is bubbled through the sulfuric anodizing electrolyte during electrolysis. This movement of the solution assures a continuous supply of “frest” electrolyte. The technique also forces the cooled electrolyte to the surface where the electrolytic energy being introduced to the constantly oxidizing outer layer of aluminum is absorbed.

Microchip Brazing Station

When Bondtec Systems designed a sophisticated microchip brazing station to provide a more efficient way to achieve wetting with even flow, minimal oxidation and less rework, it was trying to satisfy the industry’s highest quality demands. In operation, however, the station exhibited abrasive wear, staining and poor lubricity on various work surfaces, especially on the aluminum heat sink plate.

The heat sink was made of 6061 aluminum, a comparatively soft metal. At first, anodizing seemed to be the obvious solution. But the results of that treatment yielded inconsistent results. Moreover, the anodizing did not harden the aluminum surface. The final solution turned out to be treatment with General Magnaplate’s TUFRAm coating. The surface enhancing coating hardened the aluminum to previously unattainable levels. ASTM Taber abrasion tests showed the TUFRAm coated surface to have greater abrasion resistance than case-hardened steel or hard chromium plate.

Equally important, the process left a permanent, dry-lubricated surface on the aluminum. This not only reduces friction but also provides a lubricity which imparts significantly improved release properties. Microchips could now be assembled much more efficiently, without the use of the tweezers previously required by the chip assemblers.

Blanking Dies For Coin Minting

The world famous Franklin Mint must achieve close to flawless perfection in the coins, medals and medallions it mints and markets.

To produce these coins, circular blanks are punched out of long strips of sterling, copper or bronze. They are then burnished and coined. Because the metals are soft, it was difficult — before the use of these coatings — to attain their consistent release from the punch dies. Abrasive wear caused deterioration of the smooth die surfaces, further preventing quick release of the coins. Die hangups and machine jams caused production downtime. In addition, burrs and other die surface deformation caused a high reject rate.

Many different coatings were unsuccessfully applied to the male and female dies. However, when General Magnaplate’s MAGNAGOLD® was tried, that coating provided a permanent, wear resistant surface. Hangups and burring came to an end. Rejects were virtually eliminated. The operating life of the dies was extended. Precision improved.

Coating PET Plastic Injection Molds

Johnson Controls specializes in distinctively styled, recyclable injection blow molded PET (polyethylene terephthalate) food and beverage containers ranging in size
Excimer Laser Gas Corrosion

A critical problem inherent in the design of gas lasers is to prevent the exposure of their metal surfaces to corrosive gases released during the lasing process — xenon-chloride, free hydrogen, and free chlorine. This could be avoided by using corrosion-resistant nickel at corrosion-prone areas. However, this has two negative aspects — cost and weight. That was the problem facing General Dynamics Laser Systems Laboratory as it planned manufacture of X-ray, pre-ionized discharge UV excimer lasers for military and commercial applications.

By using Magnaplate’s synergistic coating technology to protect the laser’s surfaces from the corrosive gases, General Dynamics was able to fabricate almost all the laser parts from 6061 aluminum. This resulted in savings in substantial economies in both cost and weight.

Industrial Robots Resist Wear

Automation Engineering designs and manufactures custom robotic systems that perform complicated manufacturing tasks. The company sought a coating to give the robots’ steel parts such characteristics as extreme hardness as well as corrosion resistance superior to chrome plate. It also wanted a coating to provide dry lubricated surfaces that reduce drag and friction.

First, black oxidizing was tried without notable success. But when the relevant parts were coated with Magnaplate HMFB, it created a smooth, slippery surface with an extremely fine, dense micro crystalline layer which was free of cracks and pores. This resulted in increased service life and a gleaming mirror finish which so improved the appearance that sales of the robot also increased.

Tunneling Under the English Channel

Linking up England with France by tunneling 14 miles under the Channel created down-to-earth challenges requiring technological assistance from General Magnaplate. Components of the Robbins Company’s huge steel tunnel bores were coated with surface enhancing NEDOX to protect them against the corrosive conditions inside the tunnel. Parts treated with as little as a .001" coating show little or no corrosion after 14 months of continuous exposure to salt water and salt spray. The dry-lubricated surface produced also aided in maintenance work by facilitating necessary disassembly and reassembly of the boring machines’ components.

Back to the challenges of a Harsh Environment — Earth Orbit

While the company’s scientists and technology specialists worked to solve the down-to-earth challenges of metal surfaces and parts used in manufacturing and processing, they also kept their eyes — and their hands — on the unique challenges of Space exploration.

As previously noted, metal surfaces must be specially treated just to withstand the “passive” rigors of Space. When those metals must also be actively worked on in Space — as astronauts have been doing for years during Extra Vehicular Activities (EVA’s or Space walks) — the metallurgical challenges are even more acute.

Consider these adventures in space metallurgy that followed years of pioneering breakthroughs in the development of surface enhancement coatings for space.

Trial Run On Space Station Construction

In the late 1980, two shuttle astronauts on an EVA practiced construction techniques required in the
assembly of a permanent orbiting Space station. It was given the jawbreaking title of Assembly Concept for Construction of Erectable Space Structure (ACCESS) by NASA. In its operation, two astronauts worked without tools to assemble and then disassemble a 45’ long metal truss, consisting of ten triangular segments. Each segment includes struts that are connected to nodal joints with built-in quick-attachment and quick-release locking sleeves. All this permits one-handed construction.

Magnaplate coatings were used on the aluminum and steel members of the structure, greatly enhancing the hardness and abrasion resistance of the metals and providing a high level of dry lubricity. These proved key to the successful space station construction trail run.

Repairing the Hubble Telescope

During the Hubble Repair mission in early December 1993, the cargo bay of the shuttle Endeavor featured special guide rails coated with Magnaplate’s TUFRAM H+ and marked with highly visible positioning lines and arrows of MAGNAGLOW™, a fluorescent coating. The guide rails served as directional, alignment, and positioning guides for the astronauts during the removal and restowing of astronomical instruments in the cargo bay. The surface enhancement coatings used not only had to be tough and corrosion-resistant, but also offer the high visibility required in the extreme and variant light conditions of Earth orbit.

The Design Engineer’s Frontier

Wherever metal parts are used — from the drill casings that retrieved lunar samples to extruders on pasta making machines — design engineers are always looking for ways to achieve superior resistance to wear, abrasion, corrosion and chemical attack. They also may seek to provide metal parts with dry lubrication, dielectric strength, hardness, conductivity, mold release, or many other performance characteristics. Great strides in product performance have come through the use of new finishes and surface enhancement coatings which provide these characteristics.

Most of these advances come from smaller firms started by entrepreneurs who are driven by inventiveness, inquisitiveness and a thirst for growth — companies like “Synergistic” coating pioneer General Magnaplate. These companies match their talents, experience and knowledge with innovative design engineers to expand the boundaries of growth and achievement both in Space and on the floors of industrial plants worldwide.

Introducing New SprayThru™ Technology by Hardwood Line

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