Less Is More

A new generation of micro-fine high technology coatings promise to increase durability in the harshest of conditions. Ian Haggan, Tecvac, UK, outlines the processes and materials available.

Drilling for and producing oil and gas are uniquely aggressive operating environments that can cause extensive and expensive damage to plant. Avoidable high levels of maintenance restrict productive time and undermine operational efficiency and return on investment. The cost of corrosion alone to the oil and gas industry in the US has been estimated at US$ 8 billion annually.

Damaging chemical agents commonly encountered include salt/saline environments, hydrogen sulphide, carbon dioxide and methane. High pressure fluid and gas flow, the presence of drilling debris and rust particles can cause further physical damage. Metal on metal contact in pumps, compressors, engines, generators and other plant also causes long-term wear that may be aggravated by environmental factors.

Items of plant that may present particular problems include directional drilling control pistons, mud pump sleeves, wellhead isolation tools, coupling systems, hydraulic fracturing tools and de-sanding systems such as hydro-cyclones.

Conventionally, problems of wear, erosion and corrosion in these components would have been addressed by various methods. Substituting steel for more resilient and corrosion-resistant materials such as Inconel and Hastelloy is one answer. Coating surfaces by thermal spray, the use of electroplated chrome finishes or employing polymer linings such as PTFE is another solution.

Each of these has drawbacks. Thermal spray coating is a line of sight process that cannot deal with complex internal shapes, so some areas will be poorly protected. Some variants of this process also produce a rough internal surface that requires further labour-intensive grinding and polishing to give a surface that will improve flow characteristics.

Electroplated chrome plating (ECP) is likewise an expensive multi-stage process that is also falling out of favour because of the harsh and hazardous chemicals that it uses and potential harm that these could cause to the environment. Polymer coatings are commonly applied by spraying or dip coating. These provide a degree of lubricity, but are not suited to high temperatures or more aggressive wear environments.

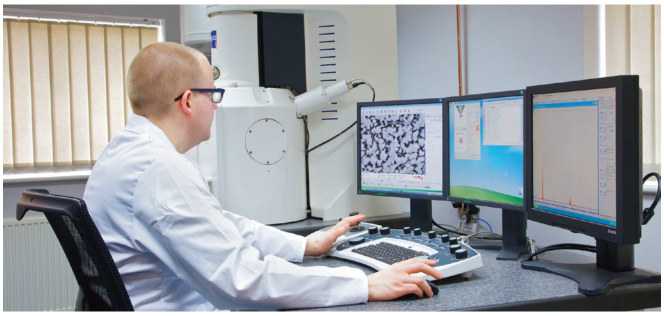

Figure 1. *Advanced microscopy enables the surface characteristics of the substrate to be examined and photographed for comparison to that of treated samples.*

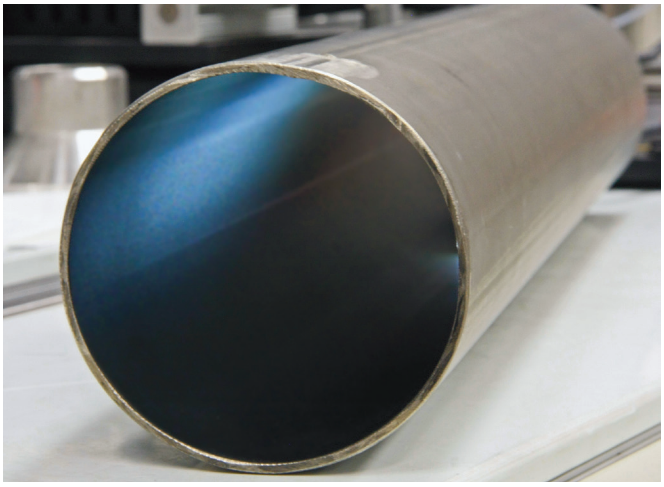

Figure 2. *Pipes of up to 3 m in length can be coated using the PECVD technique. This provides even application over the entire length of the pipe and a smooth pinhole free finish.*

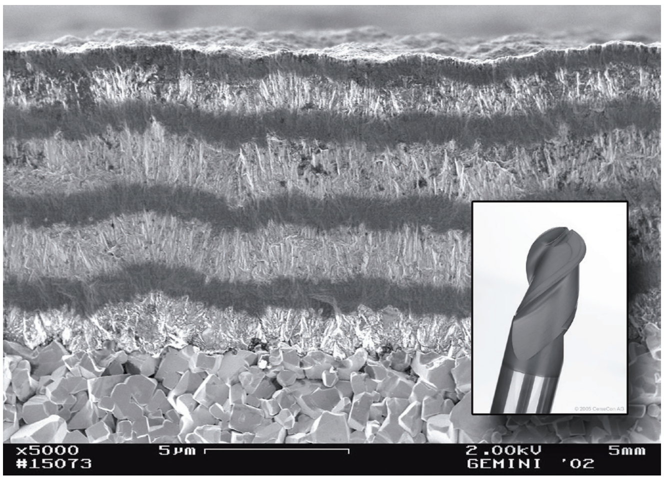

Figure 3. *Diamond and other coatings can be applied in multiple layers by the PVD method, during the same process cycle, to create surfaces that have extreme resistance to erosion and wear.*

PVD and PECVD applied resistant films

Plasma enhanced chemical vapour deposition (PECVD) is widely used to apply even, pinhole free, thin films of highly resistive diamond-like carbon (DLC), titanium carbide or other resilient coatings to components. Until recently it has not been possible to apply such films to the inner surfaces of pipes and hollow vessels. However, following the introduction of the InnerArmor process, developed by Sub-One of California, this can now be achieved with consistent results. The process is particularly suited to the internal coating or pipes or other hollow vessels.

The InnerArmor process, available from Tecvac and other processors, uses the pipe or process vessel to be coated as a reaction cell. Insulated sleeves link this to the positively charged anodes via which the source gas, at a prescribed temperature and pressure, is pumped through the void. Ionisation of the gas results in even deposition of the smooth glass-like coating on the entire inner surface of the pipe or vessel.

Once set-up, the process can be completely automated, producing a consistent and reliable finish. In addition to protecting the vessel from attrition by the pipe contents, the process can also prevent pipe contents being contaminated by worn substrate debris thus preserving product quality and value.

The process is competitive to other alternatives. It is environmentally benign, prevents corrosion, is suited for all steels and alloys, will resist wear, even in harsh environments, will perform at high temperatures and has chemical resistance to acids, bases and organic compounds. Moreover, coatings are naturally hydrophobic (water shedding) and therefore improve the flow characteristics of pipes and vessels.

Typical coatings vary from 30 - 80 µm, so tolerances between moving parts in most mechanical equipment are not compromised. Coatings can be optimised for hardness, wear and erosion resistance or to tolerate acids, salts, hydrogen sulphide or fluids with abrasive solids such as sand and grit. The target coating thickness can be made up of several layers, producing a low stress and highly resilient surface because fatigue cracks in the surface layer cannot propagate and penetrate beyond the initial layer.

The PECVD process can be used to coat components of all sizes. Most of the InnerArmor equipment is used for larger pipes, up to 3 m and other large hollow vessels, but the technique can also be applied to smaller components.

Coating by physical vapour deposition (PVD) is another way of providing protection. The coating material is held in a small crucible within the coating chamber, which is subject to high vacuum. This material is vaporised through bombardment by an electron beam, which then combines with the selected gasses to form ceramics. The component to be coated is rotated on a rack within the chamber so that the vaporised material condenses on all of its surfaces. The evenness of deposition is assisted by having a negative charge on the component within a positively charged chamber.

The Nitron family of multi-layer coatings based on titanium, chromium, chromium/aluminium or carbon/metal carbide are applied to components using the PVD process. These coatings were originally developed for aero engine applications where resistance to the erosive forces of high velocity airflow and high temperature are required.

The coating may be applied in six to eight layers depending on the process, making a surface that complies closely with the substrate. This creates a low stress surface coating that is more resilient to delamination than a single layer coating of the same thickness.

Duplex variations of these coatings can also be applied. Where, for example, the substrate may lack surface hardness and thus be liable to gall if subjected to load, then an initial process can harden the surface to improve load bearing. This may be followed by the application of a friction resisting top coating to counter wear.

Testing and verification

Honeywell labs have conducted NACE TM-185 sour autoclave tests to assess the resistance of parts coated using the InnerArmor method. The test parts were coated and uncoated samples of 304 stainless steel. Over three days the parts were held at a temperature of 150 ˚C and a pressure of 500 psi and were exposed to aqueous, hydrocarbon and gas phases. During the aqueous phase they were subject to a 5% brine solution, during the hydrocarbon phase a 100% Xylene solution and the gas phase a mixture of 84% carbon dioxide, 15% methane and 1% hydrogen sulphide. The uncoated stainless steel part demonstrated severe pitting corrosion over the entire surface, whereas the coated part showed no corrosion, even after a post-test 'holiday' interval.

During a more severe test, mild steel components were exposed to an 18% concentration of hydrochloric acid at 95 ˚C for eight hours. The untreated mild steel showed catastrophic failure whereas the InnerArmor sample was totally unaffected.

In other tests on abrasive wear, uncoated mild steel samples were tested against samples with a 23 μm coating and hardness of 1800 Hv. Subject to a 10 min. exposure to aluminium oxide at a rate of 2g/min. and a speed of 30 m/sec. for 10 min., there was zero abrasion damage on the surface. Similar abrasion tests on downhole drilling pipes comparing uncoated hardened AISI A2 steel and 304 stainless steel, revealed that the coated material offered between 50 and 130 times greater abrasive wear resistance.

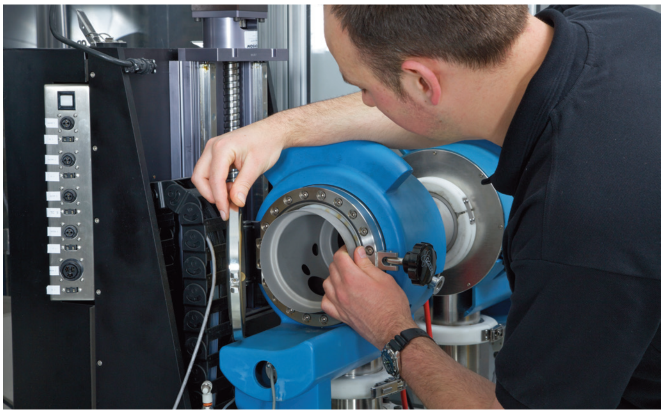

Figure 4. *PECVD machines can be used to internally coat a variety of plant items and provide total coverage of even the most complex internal shapes.*

Development

Processors have a wide range of standard coatings available. Most specialists in this field are exposed to the rigorous requirements of aerospace, motorsport and other demanding and advanced engineering fields. This enhances their experience and capability. For the majority of engineering challenges presented by oil and gas exploration and operations there will be a suitable coating and process available. Subject only to normal commercial considerations, specialist producers will be willing to refine and customise processes and develop new techniques where these are required.