Nickel-Phosphorus and Hard Chrome

Sandwich Coatings Provide Better Corrosion Protection

Microcracks in hard chrome coatings can impair their anti-corrosion properties. The combination of a hard chrome top coat and an underlayer of nickel-phosphorus brings about a huge improvement in the quality of the corrosion protection that can be provided by thin coatings.

Hard chrome coatings can provide significantly improved corrosion resistance and be made thinner if a layer of nickel-phosphorus is applied first.

Hard chrome is the most widely used top coating on components such as shock absorbers, piston rings and hydraulic parts, because of its impressive hardness and excellent abrasion resistance. However, it does also have some disadvantages, in particular, a tendency to form microcracks. Where the substrate is steel, this can lead to the early onset of corrosion. Furthermore, the risk of this occurring is higher with thick, single-layer chrome coatings.

For this reason, Umicore Galvanotechnik launched a project to test two-layer systems. The aim was for the coating underneath to give the corrosion protection, while the top layer of hard chrome provided the necessary hardness and abrasion resistance. The result is a combination of a nickel-phosphorus alloy and hard chrome (Protecore).

Alternative coating system

In order to identify the best possible combination of materials and to allow for valid comparisons with conventional coatings, different alternatives were investigated in a comprehensive series of tests. These included pure chrome surfaces and two-layer systems, such as chrome with a combination of nickel and nickel alloys. The nickel-phosphorus alloys, which were deposited both chemically and electrolytically, consisted of 88 percent nickel and 12 percent phosphorus.

Two-layer systems are superior

The coatings were applied to a 230-millimetre-long tempered steel rod made from Cf 53 (material: 1.1213) with a diameter of 13 millimetres. After grinding and polishing, its surface roughness (Ra) was less than 0.1 µm. Three standards-based corrosion tests were carried out. The first was the neutral salt spray test (NSS test in accordance with DIN-EN ISO 9227-NSS) for a maximum period of 336 hours. Secondly, the CASS or copper-accelerated acetic acid salt spray test according to DIN EN ISO 9227-CASS was run for 240 hours. A Corrodkote test in accordance with DIN 50958:212-12 was also carried out for up to 10 cycles.

The two-layer systems with a top coat of chrome and a base coat of nickel-phosphorus alloy produced the best results in these three tests. These systems demonstrated their significant superiority in the NSS test in particular. Pure chrome layers showed considerable corrosion after only 16 hours in the case of coatings with a thickness of 20 µm or after 24 hours where the thickness was 35 µm. In contrast, material

The two-layer system with a 10 µm base coat made from nickel-phosphorus alloy and a 10 µm chrome layer (left-hand block, right-hand rod) is almost unchanged after 336 hours in the neutral salt spray test (NSS test). In contrast, a 35-µm-thick chrome coating shows massive corrosion after 24 hours in the NSS test.

samples of the two-layer nickel-phosphorus and chrome systems were almost unchanged after 336 hours. The material samples in the NSS test retained their original appearance for up to 800 hours. As expected, the pure nickel-phosphorus coatings were not sufficiently abrasion resistant.

Thinner chrome layers

The most important outcome of the project is the discovery that double-layer systems not only provide considerably improved corrosion protection, but also allow the thickness of the layers to be significantly reduced. This leads to a fall in both material usage and costs. In addition, the deposition time is shorter, even though other parameters remain the same.

Another benefit is that the normal mechanical finishing required for hard chrome coatings can be reduced. This allows costs to be lowered in every area of the production process without compromising on the quality of the coating.

Thinner chrome layers are also desirable from an environmental perspective. If the thickness of a chrome coating is reduced from 50 µm to 10 µm, smaller quantities of process materials such as chromic acid are needed. In addition, the proportion of Pb-CrO4 drops if conventional lead anodes are used.

In practice, systems consisting of 10-µm-thick nickel-phosphorus and chrome layers have proved to be a good choice. However, the thicknesses of the layers and the combinations can be varied depending on the application. An additional layer, such as nickel, can also be applied. For example, a further nickel coating with a thickness of 10 µm on the base substrate is a possible option for the lifting arms of excavators. Good results have been achieved on shock absorbers with both a two-layer system (10 µm nickel-phosphorus and 10 µm chrome) and a three-layer coating (8 µm nickel, 2 µm nickel-phosphorus and 10 µm chrome).

Electrolytic application

The application of the nickel-phosphorus layer using an electrolytic rather than a chemical process brings further benefits. It is true that an electricity supply and accessories such as rectifiers and anodes are needed and another disadvantage is that the distribution of the coating thickness is dependent on the current density. However, this is not relevant for cylindrical components and bars. Despite this, the benefits are considerable. The electrolyte mixtures can be managed and analysed easily. They are less sensitive to changes in temperature and, furthermore, contamination with metal particles is not critical. In chemical nickel processes this can lead to the self-destruction of the electrolyte. Finally, a nickel-phosphorus layer can be applied electrolytically without the use of heavy metals, which are not found in either the electrolyte or the coating.

As a result of the project, Umicore Galvanotechnik has developed a precisely formulated nickel-phosphorus electrolyte known as Niphos which provides excellent protection, in particular in combination with a hard chrome layer, and is perfectly designed to meet the market requirements of the chrome plating industry.

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