Popular science summary

Titanium Surface Properties

A comparison of titanium between two suppliers

The company Alfa Laval produces heat exchangers used in many applications in a variety of industries. In these heat exchanges titanium metal is often used, and this titanium is mostly bought from two suppliers. The titanium from these two suppliers has been assumed to be indistinguishable from each other but in one case titanium from one supplier was damaged more than the other when used in the same application. Because of this the properties of the titanium from the two suppliers were studied to see if there are any discernible differences.

To examine the available titanium samples a wide variety of methods were used. Properties studied where surface energy, surface roughness, hardness, grain size and crystal directions, corrosion rate. and tensile tests. Finally the surface elemental composition was studied using a technique called Glow Discharge Optical Emission Spectrometry (GD-OES)

When scrutinizing information from the suppliers it was discovered that the last production step differs between the two suppliers. The last production step for Supplier 1 is to heat the titanium to a high temperature in air. When this is done, dirt and other things from the air gets stuck in the surface layer of the titanium, so to remove this Supplier 1 washes the surface with a powerful acid to remove this thin layer of contaminated titanium. Supplier 2 instead heats the titanium in vacuum, trying to avoid these contaminants, and thus does not wash with acid. This leads to some differences in the surfaces of the titanium from the two suppliers.

The results showed that there were some small differences between the suppliers. Supplier 1 titanium had for example smaller grain size and was slightly softer. But the largest difference was shown in the corrosion tests.

Titanium is usually a very corrosion resistant metal due to a protective layer of titanium dioxide that forms over the surface of the metal when exposed to air. However, this layer is removed in some acids, such as hydrochloric acid. When testing the corrosion rate something unexpected happened, the material from one supplier corroded at the speed that was expected by titanium whereas the material from the other supplier did not corrode at all. Instead the samples from this supplier changed colour from the grey of metallic titanium to a variety of other colours like red and yellow.

A theory for why this happened is that there is carbon close to the surface of the titanium and in the acidic environment this carbon helps make the oxide layer grow thicker instead of removing it. What might have happened is that lubricants, which are made mainly from carbon-based products were used in the production of the titanium that was studied. During the titanium production carbon from these lubricants got stuck in the surface layer of the material. When the supplier that heats the titanium in air washes the titanium with acid this carbon is removed. But since the other supplier does not do this the carbon remains in their samples, leading to the unexpected corrosion results.

In the GD-OES analysis samples were blasted with argon ions, removing a very thin layer of material. Using this the elemental compositions at different analysis depths could be measured and this showed that there was indeed more carbon in the samples that did not corrode supporting the theory above. Note that this is still a theory and that this is the cause of the unexpected corrosion results is not verified.