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Enhancing Titanium Friction & Wear Properties

For all of the known benefits of titanium alloys in all sorts of applications, from medical to aerospace to automotive, titanium is also known to exhibit poor tribological properties. That is, it has a high coefficient of friction (COF) when in moving contact with essentially all structural metals, resulting in poor sliding and adhesive wear resistance that leads to failure by galling (cold welding). Because of this, metal-to-metal applications encountering friction and wear considerations require a surface treatment for adequate serviceability. One such treatment is solution nitriding, which is performed in a vacuum furnace using partial pressure nitrogen gas at elevated temperatures in the annealing range. Solution nitriding is classified as a diffusion process where nitrogen gas dissociates and nascent nitrogen is adsorbed and diffused into the titanium matrix. Like other diffusion processes, the depth of the diffusion zone is dependent on the time of the treatment. For alloy Ti-6Al-4V with a core hardness of 30 HRC, Solar Atmospheres has generated hardnesses as high as the mid-60's to upper-60's HRC (converted from HV 25gf) at a depth of 0.0076mm (0.0003"), followed by a gradual decrease in hardness to the core over a distance of 0.25mm (0.01"). Shorter cycle times have produced hardnesses in the mid-50's to high-50's HRC and shallower total case depths.

As an example of its capability, Solar Atmospheres solution nitrided Ti-6Al-4V test samples for a study performed by Oak Ridge National Laboratory. The work was both presented and published under the title "Surface engineering to improve the durability and lubricity of Ti–6Al–4V alloy"; Bansal, Eryilmaz, Blau. The focus of the study was to evaluate titanium for weight reduction in heavy truck diesel engines. A wide variety of surface treatments were evaluated in a friction and wear study that included: "diffusion treatments, hard coatings (TiN and CrN [PVD]), a soft coating (Cu–Ni–In), titanium-matrix TiB2 in situ-formed composite, and shot peening". Here is a reporting of two conclusions from the study:

> "(b) CrN coated Ti64 specimens had the least amount of wear, followed closely by DLC (diamond-like-carbon) coated Ti64 specimens.
> (c) Nitrided (Solar's process) and oxygen diffusion treated specimens yielded the lowest COF, and their wear is also comparable to those of CrN and DLC coated specimens."

Solution nitriding is not a coating like CrN or DLC; it's a thermochemical heat treatment where nitrogen becomes an integral part of the titanium matrix. So unlike a coating, it does not have to initially bond well to work and it will not spall away from the base metal. That's because it is the base metal at the surface; it's a metallurgical case that significantly strengthens the base metal just as conventional carburizing and nitriding of steel does, allowing for increased service loads along with friction and wear performance properties.

Solution nitriding of titanium could open new markets for anyone wanting to use titanium in a friction and wear service application. Solar Atmospheres has experience with this new process and has varying size vacuum furnaces to perform the task. We suggest starting with trial runs for functional testing. The goal is to develop the best process specifically suited to your application for your parts. For more information or questions, contact Don Jordan (don@solaratm.com) or by phone at (215) 721 1502 x1206.