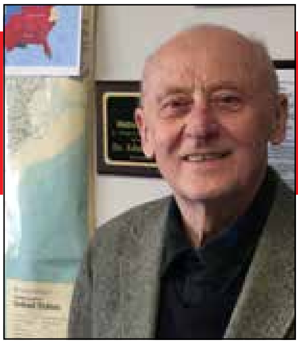
EDWARD ROLINSKI
SENIOR SCIENTIST
ADVANCED HEAT TREAT CORP.



MODERN NITRIDING TECHNIQUES FOR GEAR APPLICATIONS

Among thermochemical methods, the processes of plasma nitriding and gas nitriding have progressed in the industry to increase gear performance.

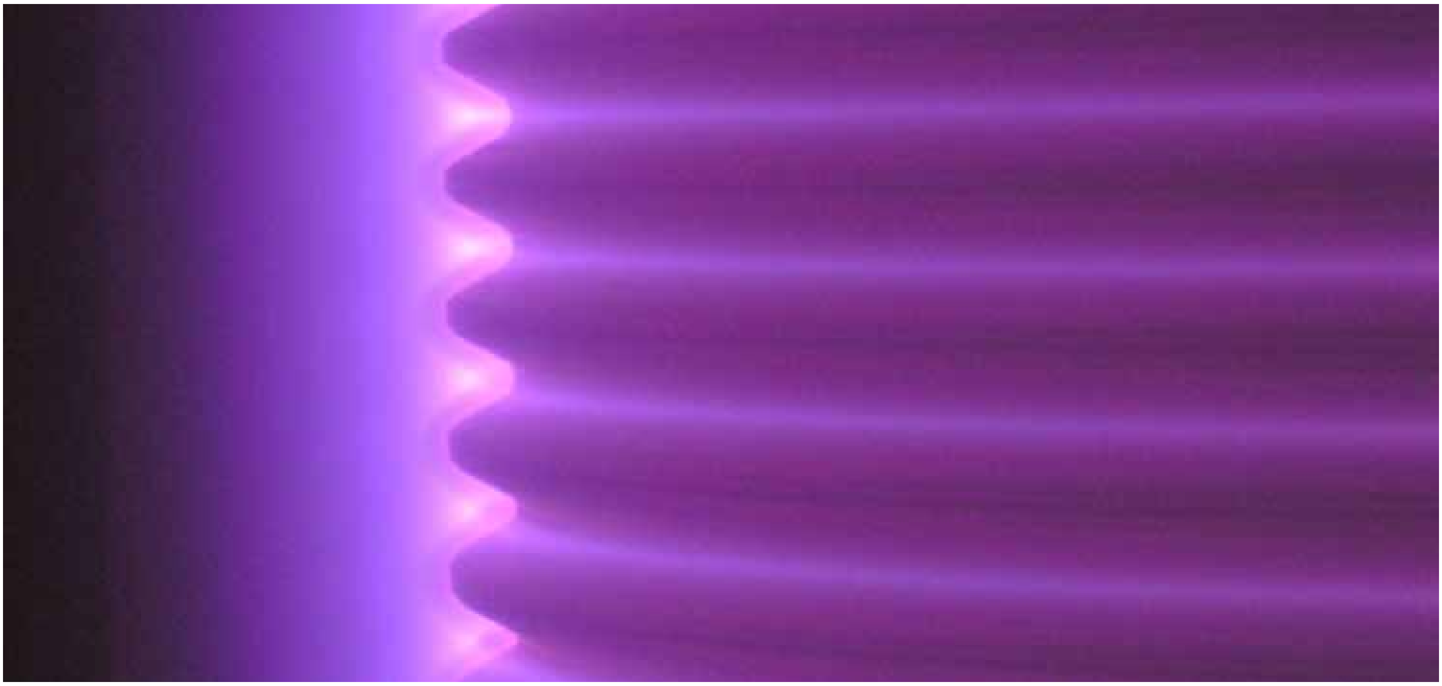


Figure 1: Worm gear during plasma nitriding (photo courtesy of Advanced Heat Treat Corp., Monroe, Michigan)

IMPROVING SURFACE PROPERTIES OF GEARS CAN BE extremely beneficial since many failures start at the surface in the contact area between the teeth [1]. Rolling contact fatigue properties of the gear surface are improved when a hard diffusion layer — with the compressive residual stresses built into it by the thermochemical surface engineering methods — are applied. Such a layer prevents or delays the formation of premature surface and subsurface cracks, core crashing, or subsurface fatigue.

Well-known methods of the thermochemical treatments applied for gears include carburizing, carbonitriding, ferritic nitrocarburizing, and nitriding [2]. Although carburizing produces the thickest layer, it is carried out at a high temperature, therefore, it must be followed by quenching and tempering operations. That may cause some unwanted distortion and a need for more aggressive final machining. Nitriding is typically performed at a temperature of 390-570°C, depending on the type of steel and the case depth requirements, therefore, it is considered as a distortion-free process. Nitriding of titanium gears is carried out at above 690°C (1,274°F).

A significant increase in a gear's performance can be realized by using modern nitriding techniques. The process of nitriding is one of the most promising of the verity of many thermochemical methods known to the gear industry. For a long time, gas nitriding was used for gear applications in combination with a final grinding operation. This machining process was necessary because the layer that was formed during gas nitriding had a brittle and hard layer at the surface, called a white layer, which was built of iron nitrides that were frequently too thick and porous. It was not until the late 1960s to 1970s when the process of ion nitriding (or plasma nitriding) was introduced and found full acceptance as a panacea for the aforementioned problems of the gas nitriding process.

Ion nitriding is carried out in a vacuum with a very low partial pressure of nitrogen reaching no more than 5 mbar. The process is carried out in the DC-pulse glow discharge/plasma and can be seen through the port window (see Figure 1), and it's characterized by the sputtering effect of the surface atoms by high-energy ions of nitrogen. Both low partial pressure of nitrogen as well as the sputtering result in the formation of a very dense white layer and with an absolutely controllable thickness at the surface of the gear [3]. In many situations, no final machining is required since post-nitriding surface roughness changes are minimal, and the dimensional changes are almost non-existing because the process is carried out at a temperature well below the transition of ferrite to austenite. Also, the process of ion/plasma nitriding is beneficial in many applications as it offers a simple, local masking or protecting from hardening if required. Typical case depth produced either by plasma or gas nitriding is in the range of 0.3-0.6 mm, although a much deeper case reaching 1 mm (0.04 inch) in thickness can be produced in a typical 3-percent Cr steel used for gears [4].

Plasma-nitrided gears made of titanium alloys achieve a uniform gold-color characteristic of titanium nitride, TiN, formed at the surface (see Figure 2). The nitride is not a coating like one used for cutting tools, but rather a diffusion-type layer supported by Ti_2N, Ti_2AlN, and other nitrides and a much deeper diffusion layer of α-titanium enriched with nitrogen. The layer has excellent tribological properties.

Figure 2: Titanium $\alpha+\beta$ alloy gear for aerospace engine after plasma nitriding (photo courtesy of Advanced Heat Treat Corp., Waterloo, Iowa)

The progress achieved in the industry since the introduction of plasma nitriding has stimulated more research and development in the gas nitriding field, resulting in the implementation of superior process control methods and reliable atmosphere measuring devices such as hydrogen and oxygen probes [1]. This has also afforded the development of a nitriding potential-controlled process, which offers control of the white layer structure and its thickness and provides the ability to treat the entire gear or gear component uniformly [1]. However, in the plasma nitriding process, masking or local protection from the treatment is comparatively simpler than in the gas nitriding process, which requires galvanic copper plating.

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ABOUT THE AUTHOR: Dr. Edward Rolinski received his M.S. in manufacturing technology in Warsaw, Poland, and received his doctorate for his research on phenomenon in the ion nitriding process. He has taught physical metallurgy and surface engineering and received his ScD (habilitation) for studying plasma nitriding of titanium. Rolinski is a senior scientist at Advanced Heat Treat Corp. in Monroe, Michigan, solving technical problems and developing technologies. For more information, contact him at doctorglow@ion-nitriding.com or visit www.ahtweb.com.