



Fig. 1. Load of 100% sintered PH turbocharger union rings during plasma nitriding. (Note complex geometry of the part.)

# Plasma, Gas Nitriding and Nitrocarburizing for Engineering Components and Metal-Forming Tools

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Wear, corrosion and fatigue properties are strongly dependent on surface quality and its modifications.<sup>1-4</sup> Thermochemical methods such as gas and plasma nitriding allow for enhancement of these properties in most severely loaded (mechanically and/or chemically) applications without causing any changes in dimensions of the treated objects.

**G**as nitriding, despite its long history, is still a subject of extensive studies. There are publications presenting new inventions, which have made the process a fully controllable method in the last 30 years.<sup>5-8</sup> Plasma nitriding, on the other hand, is growing fast as a well-controlled, low nitriding-potential process, which also has many other benefits.<sup>9</sup> Modern nitriding methods are now described in academic textbooks as well as in many other publications.<sup>10-12</sup>

Differences in the mechanisms of plasma- and gas-nitriding methods have an impact on the usage of both processes. Focusing on the most proper applications characteristic for each method is important. Plasma nitriding is called a low nitriding-potential process because of its natural ability to produce layers with the thin compound zone.<sup>13</sup> Also, penetration of small cracks and porosities with plasma nitriding is very limited. The process is therefore well-suited for treating low-density powder-metal/sintered products. Plasma's ability to activate passive surfaces makes it very useful in hardening stainless steels and other nonferrous alloys (titanium and nickel). The method is also known for its usage when effective selective hardening is required.

Alternatively, the controllable gas-nitriding method allows for precise nitriding at a low and a high nitriding potential. It is very effective in achieving layers with a thin or thick compound zone in applications where 100% surface treatment is required. This is especially the case when a much thicker compound layer is required than is possible to produce with plasma nitriding.

Modern applications of the two nitriding methods – plasma and gas – should mostly be based on technical rationale of the specific requirements, which can be achieved economically using the most proper method in a given situation.

## Applications of Plasma Nitriding

Applications of plasma nitriding are very broad. Plasma nitriding is the answer to many problems caused by the abrasive wear of various tools used in the plastic and metal-forming industries. Examples involve feed screws, barrels, backflow valves, nozzles, molds and other components of plastic machinery subjected to conditions of extreme wear from fiberglass-containing plastic.

Products requiring a thin compound layer and extensive masking are growing in demand (e.g., Fig. 1) forged crankshafts in which threaded holes and counterweights need to be masked). Despite its universality, the best applications of plasma nitriding are those products made of stainless alloys, sintered metals or titanium, for which the parts are large and selective hardening is required.

## Stainless Steel Products

Both plasma and gas nitriding can be used to treat stainless steels. Plasma nitriding, however, has unparalleled ability to activate the most difficult alloys. The gas method, in those situations, needs an additional activating step with very aggressive chemicals or extensive mechanical blasting before the process can start. The sufficient sputtering rate of stainless steel can be achieved in nitrogen-hydrogen plasma to cause activation of its surface. Therefore, plasma can be considered as a method especially suited for treating those alloys. A good example would be 316 steel, such as the sintered-metal union rings shown in Fig. 1 and 17-4 PH small-pitch gears shown in Fig. 2. Despite complex part geometry, plasma nitriding produced a uniform layer in both situations.

## Titanium-Alloy Products

Frictional properties as well as corrosion resistance of titanium-alloy products are significantly enhanced by plasma nitriding.

<sup>14</sup> Nitriding leads to formation of the multi-zone layer, the outer portion of which is the TiN-type nitride with a characteristic gold color. Figure 3 shows titanium-alloy components after plasma nitriding.

## Large Products Requiring Extensive Masking/Selective Hardening

Until recently, case hardening has been used for heat treating gears, but plasma nitriding has shown increasing interest because of minimal to no distortion. This means there is no need to grind the tooth form after the treatment, and the products can be put directly into service. The technique can be applied to very small and very large gears (Figs. 2, 4). Typical gear failure modes are bending fatigue, pitting, microspitting, scuffing and wear.<sup>15</sup> Nitriding increases wear and scuffing (scoring) resistance of the tooth flanks, bending fatigue resistance at the tooth root as well as the rolling-contact fatigue (RCF) resistance of the gear-teeth surface. RCF typically leads to surface or subsurface-induced cracks, which are greatly minimized by the presence of the nitrided layer. Nitriding also produces high resistance to tempering (i.e., increases the resistance of the steel to softening at slightly elevated temperatures).



Fig. 2. Photomicrograph of plasma-nitrided 17-4 PH steel gear with diametral pitch (number of teeth per inch of pitch diameter) of 48 (50: 3% nitral)

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