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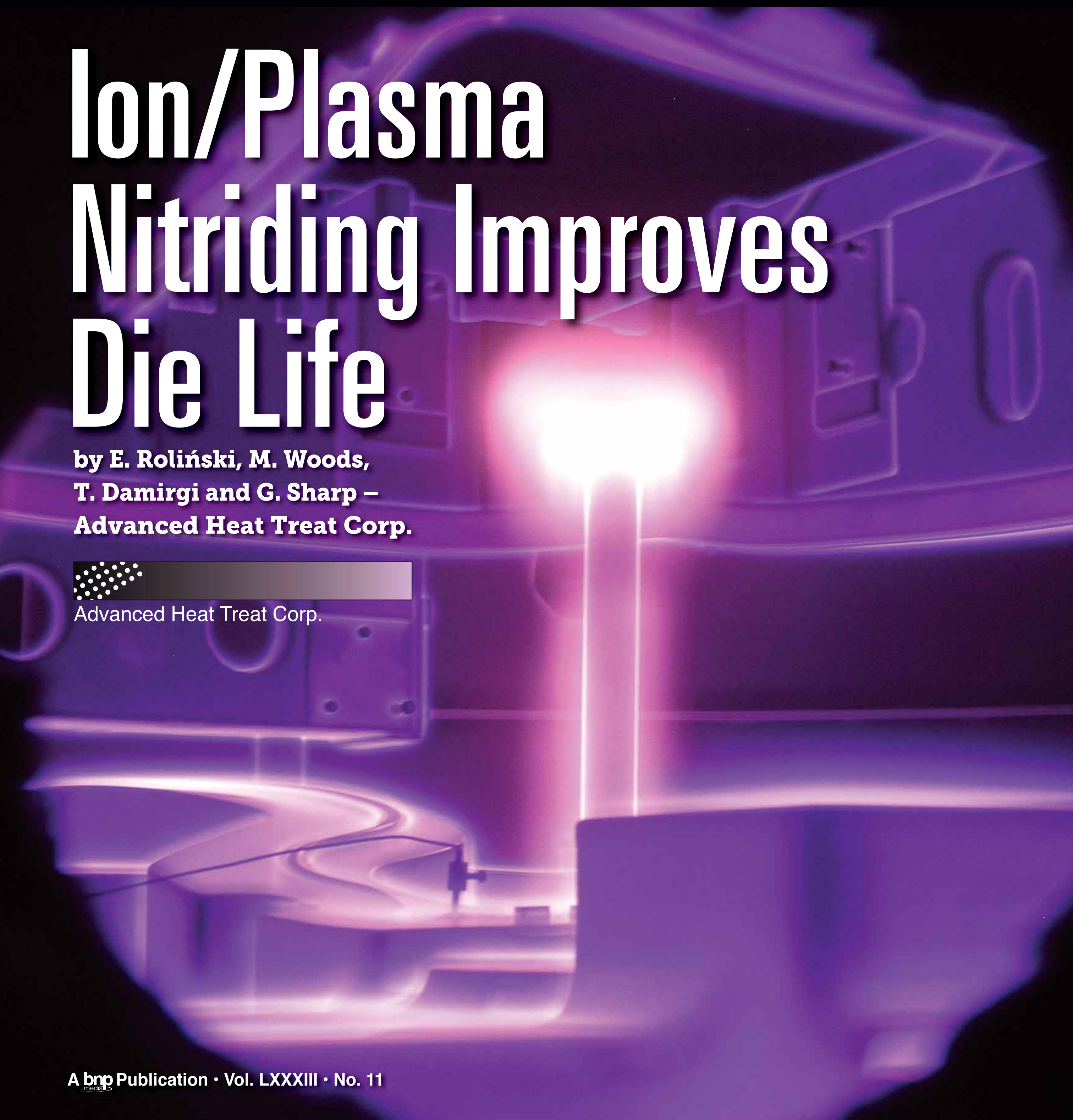

Ion/Plasma Nitriding Improves Die Life

by E. Roliński, M. Woods, T. Damirgi and G. Sharp – Advanced Heat Treat Corp.

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Improving Performance of Stamping Dies with Ion/Plasma Nitriding

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The need for lighter and safer vehicles increases the demand for stronger steels in automotive bodies. Aerospace components have many of the same demands but on a more rigidly controlled level with a wider variety of materials. This article (and sidebar) discusses a range of applications for ion/plasma nitriding.

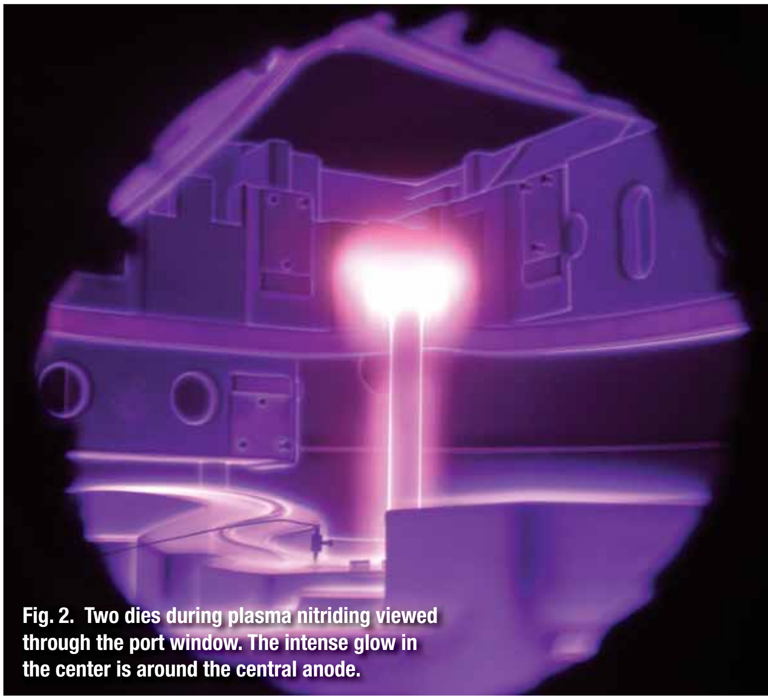

Fig. 2. Two dies during plasma nitriding viewed through the port window. The intense glow in the center is around the central anode.

The strength of steels has significantly exceeded what was used in older designs. Some of the automotive components, such as floor panels, are even made of press-hardened steels (PHS) with tensile strength reaching 1,500-1,800 MPa.[1] Therefore, challenges for stamping tools used in those applications are very high. Ion/plasma nitriding is a technique that has been very successful in surface hardening those tools in recent years.[2-7] This is especially true when the dies are made of cast materials alloyed with chromium, molybdenum and other elements that form very stable and hard nitrides. Nitrided layers formed in those alloys are very hard, and their depth exceeds 0.25 mm (0.010 inch).

Chromium plating has been historically used for stamping dies. It offers a very smooth surface with a low coefficient of friction, although not as low as ion-nitrided cast materials.[2] Limitations of chromium plating seem to be strained as higher-strength steels become harder than the substrate below the surface of the chromium layer.

With the ever-increasing hardness of panel materials, the surface requires more protection than just a chromium layer of 10-20 micrometers. Also, the electrolytic process of depositing chromium means that the chromium deposit will be heavier on most protruding areas and will be very thin and possibly nonexistent on recessed areas, possibly resulting in dimensional differences.

In contrast, nitriding is not a coating, so it does not chip or peel. It will provide the substrate depth hardness required to withstand a greater-impact environment, which results in less slug damage.[4-8] It also does not cause dimensional changes since the process is evenly applied on both protruding and recessed areas.

Previous surveys have shown that a chromium-plated die surface on cast iron or cast steel can see as many as 350,000-600,000 hits or panels. These numbers are decreasing because of the wider applications of advanced high-strength steels (AHSS). In the same stamping environment, however, nitriding results show quality panels well in excess of 850,000 hits with dies that are still running. One particular study showed 1.2 million panels on a floor-pan die cavity.

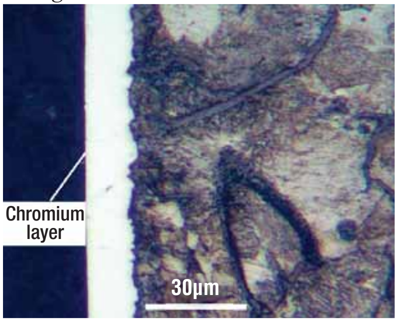

Fig. 1a. Photomicrograph of the chromium-plated G25HP cast iron

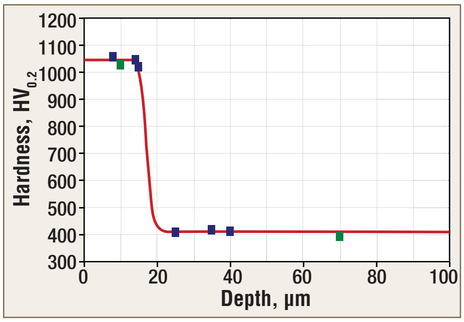

Fig. 1b. Hardness distribution in the chromium-plated G25HP cast iron

Ion/Plasma Nitriding

The process has been widely used for hardening components of large-draw dies such as punches and binders.[3-7] They are

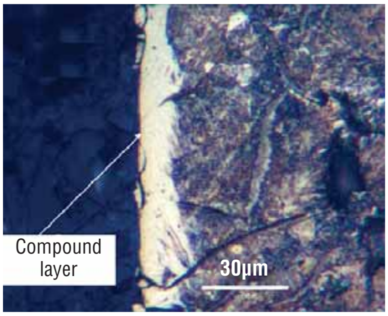

Fig. 3a. Photomicrograph of the plasma-nitrided G25HP cast iron

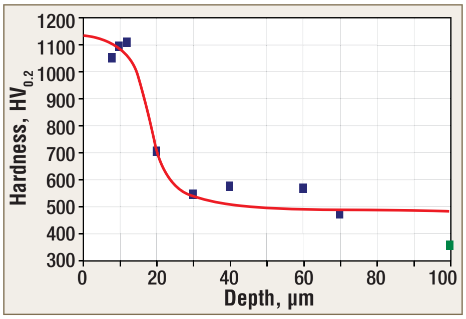

Fig. 3b. Hardness distribution in the plasma-nitrided G25HP cast iron

Fig. 4. Stamping die after plasma nitriding

typically made of gray or ductile cast irons (such as G2500, G3500, D5506 and others) as well as cast steels, including S0050A and D-2. The line and progressive dies as well as various inserts are made of Caldie, M-2, S-7 and other high-quality tool steels and are often treated in a combination of ion/plasma nitriding with PVD coatings.[9]

The best option for treating monolithic, large-size die components is ion/plasma nitriding. The treatment is performed in a large vacuum vessel equipped with resistance heaters and a plasma generator. Parts are covered with glow-discharge plasma, which generates ions and active nitrogen species and causes nitriding effect. The process can be seen inside the vacuum chamber (Fig. 2).

The nitrided layer is built of compound and diffusion layers (Fig. 3). It can be very easily noted that the hardness profile in the ion/plasma-nitrided sample is more advantageous than in the chromium-plated sample. A very sharp gradient of hardness in the latter may be a reason for cracking and exfoliation of the chromium layer in the high-stress contact areas such as radii. Conversely, a smooth transition of hardness in the surface of the ion/plasma-nitrided dies is preferable for all metal-forming tools subjected to very high Hertzian stresses. It should also be noted that the stresses in nitrided surfaces are compressive.[10]

Conclusions

New generations of advanced high-strength steels (AHSS) used in the auto industry create challenging situations for stamping tools since the stress required to induce sufficient plastic deformation exceeds 400 MPa. Small tools or inserts can be made of the strongest tool steels, nitrided and PVD or CVD coated with hard and wear-resistant layers such as CrN, TiAlN, etc. to endure to the contact stresses needed for forming the steel components.

Large stamping tools are usually made of cast irons or cast steels. Hardness of such materials is typically insufficient for resisting high-contact Hertzian stresses needed in the forming operations. These tools can be induction or flame hardened, but treatments with PVC or PVD techniques are not accessible to them because of their size. Chromium plating has been used successfully in those situations for many years, but this technique has reached its limits for tools needed in forming AHSS.

Ion nitriding can produce hard surface layers in any ferrous or titanium alloy components. The nitrided layer produced in high-alloy precipitation-hardenable steels (such as 15-5 PH, 17-4 PH or others) is free of the intergranular network (IGN) and has a white layer of limited thickness, making the aerospace components resistant to wear, bending fatigue and rolling-contact fatigue (RCF).

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Ion Nitriding for Surface Hardening of Aerospace Components

High-alloy steels – such as precipitation-hardening-type martensitic 15-5 PH, semi-austenitic 17-7 PH or austenitic (superalloy) A-286 – and bearing steels like M-50 are often used for making aerospace components. These components are subjected to friction, erosion and rolling-contact fatigue (RCF).[10-13]

Nitriding allows for the formation of very hard layers in the formerly mentioned steels because of their high content of chromium, molybdenum and other elements known as nitride formers. The ion-nitriding process can also be used for surface hardening aerospace components made of titanium alloys.[7] Its hardness is very high, but it does not exceed dangerous limits.

Many parts in the field of aerospace are produced in small quantities and require a very precise heat treatment as well as well-controlled nitriding. The process is often applied

Ion Nitriding for Surface Hardening of Aerospace Components (continued from previous page)

selectively and only to the surface subjected to the friction or RCF. The components may be partially protected from the treatment by applying mechanical masking.

Ion nitriding is a well-suited technique for meeting those requirements. The process allows for precise control of not only the layer structure but also its hardness in very specific limits, which is especially important in high-alloy steels. The process of ion/plasma nitriding, also known as glow discharge nitriding, is carried out in electrical discharge with the workpiece being the cathode and the vacuum vessel being the anode.[10] The selective hardening is easily achievable through the application of mechanical masking. The process can be controlled optically through the port window (Fig. 5).

Ion Nitriding of Aerospace Components Made of High-Alloy Steels

The hardness of high-alloy steels is typically very high after nitriding, but it has to be kept below 1,100 HV to avoid creating a brittle condition in the layer. The structure of the layer in such steels as 15-8 PH and 17-4 PH should be free of the intergranular network (IGN) to avoid cracking in the layer when it is subjected to RCF or other conditions. Both of these requirements can be achieved by the proper control of the ion-nitriding process (Figs. 6-7).

Fig. 5. Ion nitriding of the crankshafts for aerospace applications; note masking plates on top of the crankshafts.

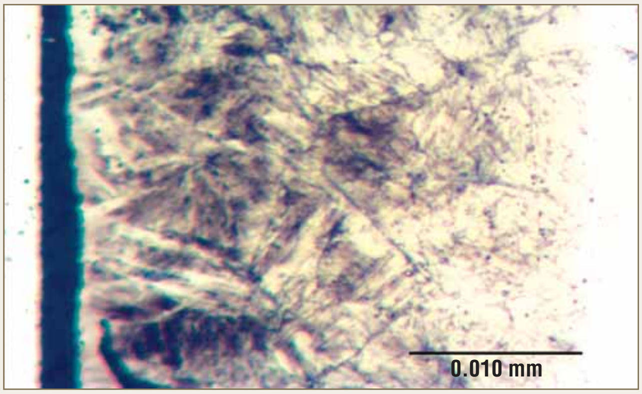

Fig. 6. Photo micrograph of 15-5 PH steel sample ion nitrided at 540°C (1004°F); nital etched

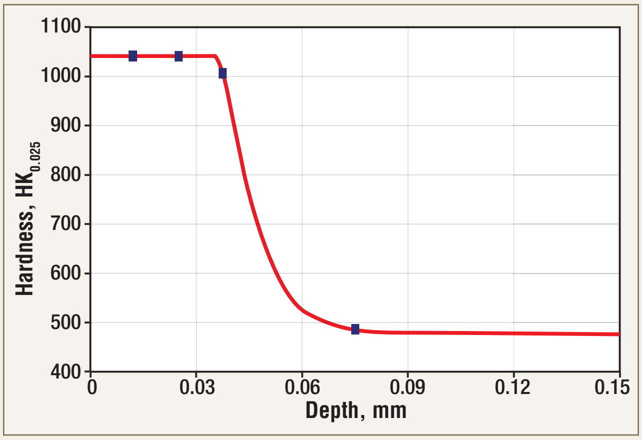

Fig. 7. Hardness profile in 15-5 PH steel sample ion nitrided at 540°C

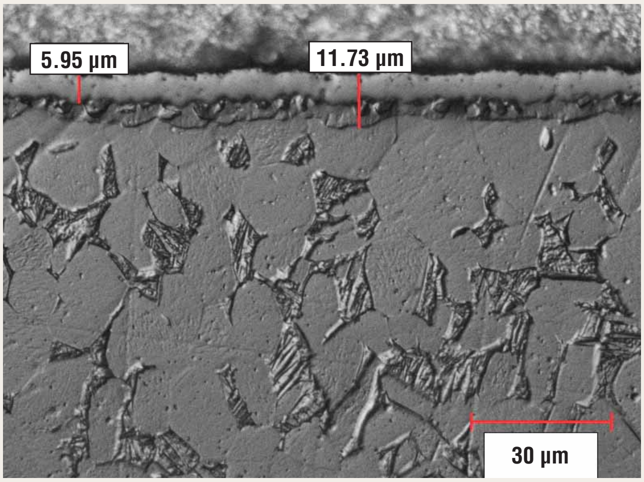

Fig. 8. Photomicrograph of 6Al4V titanium sample ion nitrided at 765ºC (1409°F); Kroll reagent

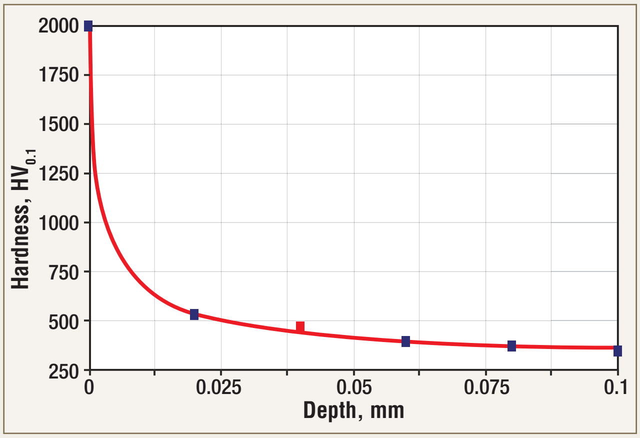

Fig. 9. Hardness profile in Ti6Al4V titanium alloy sample ion nitrided at 765ºC