# The Advantages of Ion Nitriding Gears

*This process can eliminate the need for expensive post-heat treatment operations.*

**Robert Lamont, Jr. & A. Bruce Craven**

When it comes to setting the standard for gear making, the auto industry often sets the pace. Thus when automakers went to grinding after hardening to assure precision, so did the machine shops that specialize in gearing. But in custom manufacturing of gears in small piece counts, post-heat treat grinding can grind away profits too.

One alternative that has yet to be fully exploited by the gearing industry is ion nitriding. General Motors' Allison Division has ion nitrided 4140 steel diesel engine gears, Ford has used the process for certain models, and perhaps a dozen commercial heat treaters around the United States provide ion nitriding services to machine shops. Here—from the perspective of a custom gear shop and a heat treater—are some of the advantages that ion nitriding offers gear makers.

### Advantages of Ion Nitriding

For any manufacturing operation, grinding adds not only time and labor, but also an element of risk. Grinding has become a routine part of gear making, primarily because the heat treating processes that harden load-bearing parts such as gear teeth also introduce thermal stresses that cause distortion. But unlike induction hardening, a commonly used surface hardening process in which gear teeth are hardened tooth-by-tooth or one at a time, ion nitriding introduces favorable compressive stresses.

**Table 1 — Case Depth**

| Steel Grade | Typical | Practical Maximum |
|---|---|---|
| 1045 | .001" – .002" | .002" |
| 4140 | .010" – .012" | .025" |
| 4340 | .008" – .010" | .015" |
| A-2, D-2, H-13 | .008" – .012" | .015" |
| 400 Series S/S | .004" – .006" | .010" |
| 300 Series S/S<br>PH S/S (17-4, 17-7, etc.) | .003" – .004" | .005" |

Ion nitriding is performed in a precision-sealed vacuum furnace. After the air is evacuated (to less than 100 ppm of air), a small partial pressure of hydrogen and nitrogen gas is bled into the chamber, and the vacuum is maintained at about 5 torr (atmospheric pressure is 760 torr). Then, energizing the parts to a negative (approximately 500 volt) potential initiates an electrical plasma of gaseous ions. The positively charged ions are attracted to the part, subsequently reacting with the alloy elements of the steel part to form nitrides. The nitriding temperature is significantly lower than that of induction hardening or carburizing—specifically, 950°F. Moreover, with ion nitriding, there is no need for a liquid quench, eliminating another source of adverse stresses and distortion. Eliminating most heat treat-induced distortion is critical for any manufacturer, particularly smaller machine shops with limited equipment for secondary operations such as grinding and straightening.

### Practical Applications

How do these theoretical advantages translate into everyday practice? At Atch-Mont Gear, a good customer requested a Class 10 gear with hardened teeth. A Class 10 gear is not that hard to machine, but typical practice for a 4140 gear (either annealed or pre-heat treated) would have been to induction harden the *gear teeth only* for better wear characteristics. The distortion introduced by induction hardening or carburizing lowers the class number (or precision) because of the high process temperature (in excess of 1600°F) and subsequent quench. Lacking the ability to grind all types and sizes of gears, Atch-Mont's only option for returning the gear to the required precision appeared to be sending the piece out for tooth grinding. This was cost prohibitive.

Fortunately, Atch-Mont has had some customers who requested gas nitriding with ammonia, so the company was familiar with nitriding's low-distortion benefits. Solar Atmospheres, a commercial heat treater specializing in vacuum processing, suggested the piece would be a good candidate for ion nitriding. Atch-Mont told the customer it couldn't *guarantee* Class 10, but could ion nitride and lap the gear teeth if necessary. The results were successful.

**Ion Nitriding Worm and Pinion Shafts**

Worm and pinion shafts are also good candidates for ion nitriding. Parts that are usually made from 8620 steel and carburized, or from 0.4 carbon medium alloy carbon steel and induction hardened need to be rough machined with extra material on the journals. This allows for finish machining to overcome the distortion resulting from carburizing or induction hardening. With ion nitriding, this is not a requirement.

Worm gears—typically made from 8620, 4615 or 1045 steel—have a tendency to unravel when carburized or induction hardened (because of the higher temperature process), which means they have to be ground afterwards to make them straight and true with respect to the bore (or centerline). At Atch-Mont, engineers found that by making the gears of pre-heat treated 4140 steel and ion nitriding them, nearly the same hardness could be achieved. Herringbone gears will respond with the same positive results.

At Solar Atmospheres, gears in the 10–12" diameter range are commonly ion nitrided, and gears of up to 30" in diameter can be accommodated. Gear materials most commonly ion nitrided are the medium alloys—the 4000 and 5000 series steels and, occasionally, the 6000 series steels. Stainless steel, which is very hard to gas nitride without mechanical or chemical surface treatments prior to processing, can be ion nitrided, although not as easily as the medium alloys. (The high percentage of chromium and nickel develops very hard surface nitrides that saturate the metallurgical structure quickly, making the ultimate case depths shallower than the alloy steels.)

Ion nitriding introduces minimum growth on the order of .0001—.0002" per side and requires less processing time than gas nitriding. But the real advantage for a machine shop is the reduced number of machining steps coupled with the quick turnaround, which results in faster manufacture. It can also give manufacturers more material selection choices. The resultant benefits are moderate surface hardness gains with deep case depths in medium alloy steels, high surface hardness with shallow case depths in stainless steels and high surface hardness with modest case depths in tool steels.

**Masking**

With ion nitriding, workpieces may have to be masked to insure that surface hardening occurs only where it is supposed to. Sometimes this is relatively easy; i.e., gears can be stacked, permitting nitriding of the teeth with just the topmost pieces requiring a mask to cover the face and bore. But even when individual pieces have to be masked with a stop-off paint—a time-consuming but effective process—Atch-Mont Gear feels it's well worth it to "get the gear we want."

Currently, ion nitriding is used for gears up to 30" or 36" in diameter. In fact, the authors believe it is technically feasible to produce ion nitrided gears that would compete with many carburized gear applications. Most ion nitriding heat treating shops do not have the equipment capability to handle the 30" or larger gears.

One of the factors contributing to the relative scarcity of ion nitriding is the high cost of the machinery required. As interest and demand increases, however, the large capital outlay is being overshadowed by the business potential, and companies like Solar Atmospheres are looking to this area for expansion.

It is this heavy investment in equipment, as well as a lack of education as to the potential of ion nitriding, that the authors believe have kept the process from taking off in the United States as it has in Germany and other European countries. In addition, equipment problems when ion nitriding was first introduced in this country created the image of an unreliable process that has stuck in the minds of some engineers. While this is no longer a valid objection, it is true that ion nitriding furnace operators must be carefully trained, as the process is more technically challenging than gas nitriding.

These factors need not concern custom gear makers or tool and die shops, however, since there are commercial heat treaters who have expertise in developing processes even for runs of one or two parts. With ion nitriding's ability to eliminate many secondary operations and to turn jobs around relatively quickly, it's a process worthy of the machinist's consideration. ○



*Fig. 1 — A load of gears before (left) and after ion nitriding.*

*Fig. 2 — Parts as loaded for ion nitriding on the furnace hearth plate.*

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