Ferritic Nitrocarburizing Gears to Increase Wear Resistance and Reduce Distortion

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Quality gear manufacturing depends on controlled tolerances and geometry. As a result, ferritic nitrocarburizing has become the heat treat process of choice for many gear manufacturers. The primary reasons for this are:

1. The process is performed at low temperatures, i.e. less than critical.
2. The quench methods increase fatigue strength by up to 125% without distorting. Ferritic nitrocarburizing is used in place of carburizing and hardening, carbonitriding, nitriding or in conjunction with conventional and induction hardening.
3. It establishes gradient base hardnesses, i.e. eliminates egg-shell effect on TiN, TiAlN, CrC, etc.

In addition, the process can also be applied to hobs, broaches, drills and other cutting tools.

History. Ferritic nitrocarburizing was first established in 1947 in a cyanide, salt-based batch process. It was later refined as a *gaseous ferritic nitrocarburizing process* and patented by Lucas Industries in 1961. Lucas demonstrated that they could produce surface layers identical to those produced in salt bath processes using an endothermic, ammonia-based atmosphere.

Fig. 1—.0008" Compound of White Layer on an SAE 1035 Gear, Rockwell C Hardness 75+.

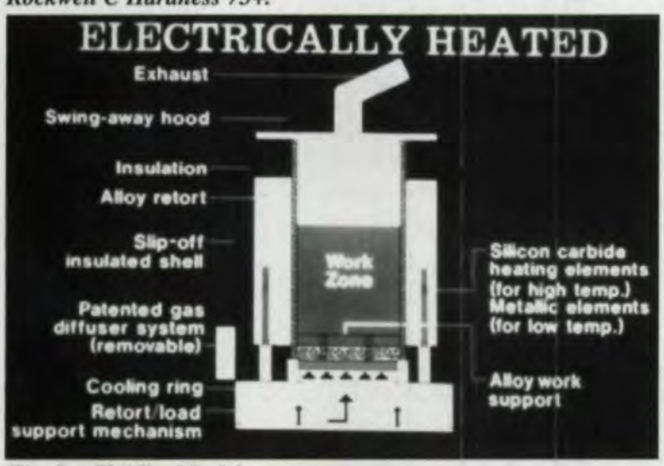

Fig. 2—Fluidized bed furnace.

The process was classified as a *"thermochemical surface treatment"* that involved the diffusion of both nitrogen and carbon into the surface of a metal at a temperature below the austenite transformation temperature. The process would yield a single phase epsilon layer with an atomic weight of Fe_2O_3. The single phase layer makes the product much more wear resistant than gas or ion nitriding, according to Dawes and Trantner (1).

In 1982, Ironbound Heat Treat developed Nitrowear® using similar atmospheres in a fluidized bed medium. Subsequently, Jack Ross, owner and founder of Ironbound, patented and licensed the process to Dynamic Metal Treating. The fluidized bed proved to be up to six times faster than the conventional atmosphere furnaces with less temperature variation, typically ±2° F from the process setpoint. Ferritic nitrocarburizing and its corrosion resistance process, Nitrowear, are similar to ion and gas nitriding but produce less brittleness and greater wear resistance.

Since taking on the license, Dynamic Metal Treating has developed and refined the process and has many of its own patents. Dynamic currently has over 25 derivatives of the process, engineered to meet the product's application and environmental requirements. The process is applied to AISI/SAE 4140, 4150, 5160, 52100, 8620, 12L14, 1144, D-2, H-13, M2, M4, M42 and T-15, just to name a few.

The Ferritic Nitrocarburizing Process

The process temperatures for ferritic nitrocarburizing are anywhere from 700°–1,200°F, depending upon the base material and the desired metallurgical properties. Since the temperature is less than the base material's critical temperature, typically 1340°F for structural and alloy steels, the parts do not experience any distortion when quenched.

During processing, nitrogen, anhydrous ammonia and a carbon producing atmosphere are introduced to the material. Based upon time, temperature and the ratio of these gases, two metallurgical characteristics are diffused (become part of the base metal) into the metal. They are referred to as:

1. Compound layer (also known as white layer or iron epsilon layer), and
2. Diffusion zone (also known as carbon and nitrogen enriched zone or total case).

The white layer has a Rockwell C hardness of 75 and greater, and the diffusion zone can be anywhere from HRC 21 to 70, depending upon the base metal. As a result, the product has:

- High wear characteristics and lower coefficient of friction values,
- Corrosion resistance greater than or equal to stainless steels,
- Low distortion, i.e. no lead, involute, tooth spacing or pitch diameter runout changes and .0002" per side linear growth on measurements over balls.
- Anti-spalling and galling properties.

These characteristics also make this a viable process for cutting tools such as hobs, broaches, etc. and an alternative to titanium nitride or other comparable coatings at one-quarter the cost. Ferritic nitrocarburizing can be applied to all ferrous metals and 400 series stainless steels. When used with precipitation hardening, special surface activation is required.

Fluidization. Fluidization is the technique where aluminum oxide (sand) behaves like a liquid while in a heat treat furnace. This is achieved by introducing gases at a given flow rate and pressure through a diffusion plate and into the sand. The diffusion plate is primarily a distribution plate that causes the pressurized sand and gases to react and become microscopically separated, thus causing the medium to move freely throughout the furnace shell. The furnace is heated electrically with silicon carbide heating elements, which are located outside the heat treat vessel's shell. The heat is rapidly distributed throughout the work zone, thereby attaining excellent furnace temperature uniformity and rapid heat transfer into the workpiece being processed. The temperature is being controlled to within ±2–5°F while conventional pit nitriding experiences ±10–25°F. On pre-heat treated materials, the ferritic nitrocarburizing cycle temperatures can mirror conventional tempering values.

The surface of the part being treated is constantly scrubbed with fresh, reactive gases. The fluidized bed methods are not inhibited by part geometry or blind holes, thus ensuring uniform metallurgical properties regardless of the part's configuration. The aluminum oxide sand particles are nonabrasive and often enhance microfinishes (see Table 1).

Before Ferritic Nitrocarburizing Ra	After Ferritic Nitrocarburizing Ra
< 4 Ra	4–8 Ra
> 4 Ra but < 16 Ra	4–12 Ra
> 16 Ra but < 32 Ra	14–28 Ra
> 32 Ra but < 125 Ra	30–125 Ra

Table 1—Changes in microfinish with the ferritic nitrocarburizing process.

Gear Type	Application
Helical, ductile iron balance gear	Balance gear, 4-cylinder engine
Splined, 8620 gear	Transfer case, 4-wheel drive
4140 and 8620 spur gears	Rear wheel drive applications
H-13 drive gears	Steel mill cranes
1035 gear	Clutch hub, transmission

Table 2—Gear types and applications that could benefit from the ferritic nitrocarburizing process.

Fig. 3—Gears and other components treated with ferritic nitrocarburizing.

The fluidized bed furnace can also perform many other heat treat processes such as nitriding, hardening (up to 1,950°F), steam bluing, annealing, stress relieving, carburizing and carbonitriding.

Gear Applications. The useful life and warranty period for many gears can be extended with ferritic nitrocarburizing. Some of the gear types and applications are listed in Table 2.

Additional benefits for gears include temper resistance (resistance to softening from heat generated in service), increased lubricity at cold start and increases in the tensile, yield and fatigue strength of the base metal as well as high compressive stresses (229,000 KSI). The process can also increase throughput and eliminate problems such as bell-mouthed I.D.s, quench cracking, retained austenite and bainite, and decarburization.

Steel Selection. Gear steels that have been successfully processed using ferritic nitrocarburizing are: 1008-1020, 12L14, 1215, 1141, 1144, 8620, 4140, 4150, 4340, ductile iron and pearlitic-malleable. The low carbon and leaded steels are selected when the application is under low, applied torsional and axial loading needing primarily wear resistance. The 11XX series is used for its increased machinability while maintaining some core hardness properties. Higher torsional and axial loading or where backlash occurs may require higher alloyed materials so that the core properties can be maintained during ferritic nitrocarburizing.

Case Depth/Quality Requirements. Quality assurance of ferritic nitrocarburizing is typically very simple. Parts are checked for file hardness per SAE J864, while white layer and diffusion zones are verified through metallography.

File hardness values for low carbon steels are typically reflected as 58 minimum with the value increasing according to the base material. White layer depths at 1000 X are anywhere from .000050–.0022" (.00127–.056 mm) and diffusion zones from .0013" to > .032" (.033–.81 mm). ○

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