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The Heat Treat Doctor®

COMPARING AND CONTRASTING CARBONITRIDING AND NITROCARBURIZING

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The terminology of heat treating is sometimes challenging. Heat treaters can be inconsistent at times, using one word when they really mean another. You have heard the terms carbonitriding and nitrocarburizing and know they are two different case-hardening processes, but what are the real differences between them? Let's learn more.

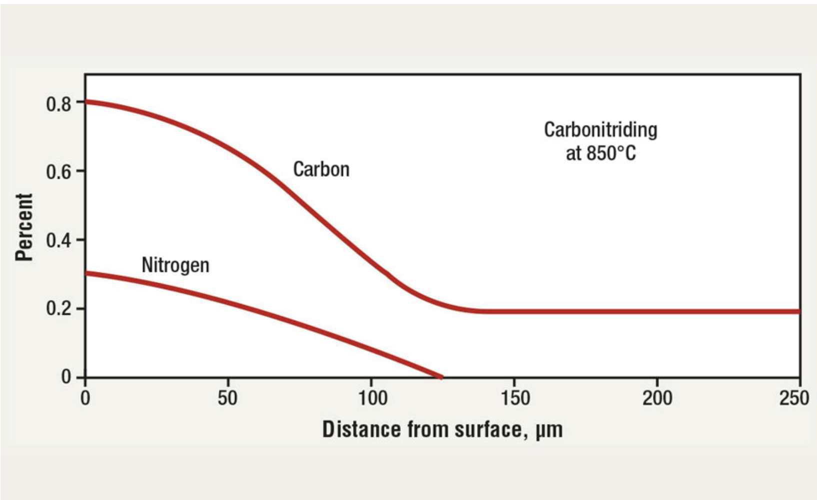
Part of our confusion stems from the fact that years ago carbonitriding was known by other names – "dry cyaniding," "gas cyaniding," "nicarbing" and (yes) "nitrocarburizing."

The Carbonitriding Process

Carbonitriding is a modified carburizing process, not a form of nitriding. This modification consists of introducing ammonia into the carburizing atmosphere in order to add nitrogen into the carburized case as it is being produced (Fig. 1).

Carbonitriding is typically done at a lower temperature than carburizing, from as low as 700-900°C (1300-1650°F), and for a shorter time than carburizing. Since nitrogen inhibits the diffusion of carbon, a combination of factors result in shallower case depths than is typical for carburized parts, typically between 0.075 mm (0.003 inch) and 0.75 mm (0.030 inch).

It is important to note that a common contributor to non-uniform case depth during carbonitriding is to introduce ammonia additions before the load is stabilized at temperature (this is a common mistake in furnaces that begin gas additions upon setpoint recovery rather than introducing a time delay for the load to reach temperature). It is important to remember as well that when the ammonia addition is halted, desorption of nitrogen will begin to occur.



The temperature range in which carbonitriding is performed is necessarily lower since the thermal decomposition of ammonia is extremely rapid, which limits nitrogen availability at higher austenitizing temperatures. A more brittle structure is formed at lower temperatures, and operating furnaces below 760°C (1400°F) can be a safety concern.

The nitrogen in carbonitrided steel enhances hardenability and makes it possible to form martensite in plain-carbon and low-alloy steels that initially have low hardenability. Examples of these steels include SAE grades 1018, 12L14 and 1117. The nitrides formed contribute to the high surface hardness. Like carbon, manganese or nickel, nitrogen is an austenite stabilizer, so retained austenite is a concern after quenching. Controlling the ammonia percentage will reduce the amount of retained austenite and should be done if hardness or wear resistance is reduced. Another consequence of high nitrogen percentages is the formation of voids or porosity. In general, it is recommended that the nitrogen content at the surface be limited to 0.40% maximum.

A common variation of the carbonitriding process is to introduce ammonia during the latter portion of the cycle, typically in the last 0.5-1 hour before the load is quenched. Any loss of hardenability that might occur due to internal (or intergranular) oxidation is partially compensated for by nitrogen absorption.

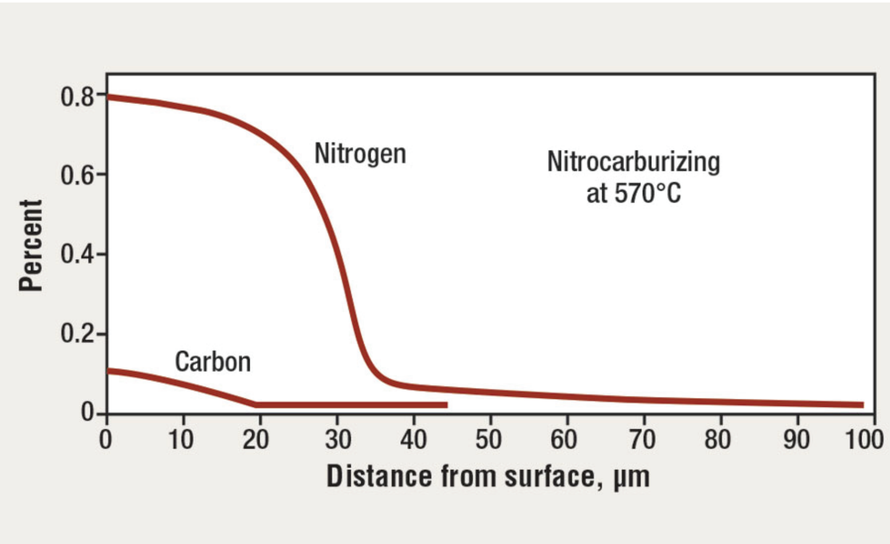
Several other points are worth mentioning. The presence of nitrogen in the carbonitrided case increases the resistance to softening on tempering (similar to some alloying elements), and the higher the nitrogen content, the higher the material's resistance to softening. Higher tempering temperatures – up to 230°C (440°F) – are often used on carbonitrided parts. The resistance to tempering manifests itself in wear properties. Carbonitrided gears, for example, exhibit better wear resistance than many carburized gears. Shallow case depth in thin-section parts of unalloyed steel, such as die-cutting punches, can be used without tempering (but this is never recommended).

The Nitrocarburizing Process

Today, "ferritic nitrocarburizing" is commonly referred to simply as "nitrocarburizing" (and hence the confusion with the older name for carbonitriding).

Ferritic Nitrocarburizing (FNC)

Nitrocarburizing is a modification of the nitriding process, not a form of carburizing. This modification consists of the simultaneous introduction of nitrogen and carbon into the steel in its ferritic condition; that is, below the temperature at which austenite begins to form during heating (Fig. 2).



Nitriding is typically performed using ammonia with or without dilution of the atmosphere with dissociated ammonia or nitrogen/hydrogen in the temperature range of 500-580°C (925-1075°F), although 565°C (1050°F) is traditionally considered the upper limit. By comparison, nitrocarburizing is typically performed in the temperature range of 550-600°C (1025-1110°F) in atmospheres of 50% endothermic gas + 50% ammonia or 60% nitrogen + 35% ammonia + 5% carbon dioxide. Other atmospheres that vary the composition, such as 40% endothermic gas + 50% ammonia +

10% air, are also used. The presence of oxygen in the atmosphere activates the kinetics of nitrogen transfer. The thickness of the "white" or "compound" layer is a function of gas composition and gas volume (flow). Nitrocarburizing is often followed by an oxidizing treatment to enhance both corrosion resistance and surface appearance.

A complex sequence is involved in the formation of a nitrocarburized case. It is important that a very thin layer of single-phase epsilon (e) carbonitride is normally formed between 450°C (840°F) and 590°C (1095°F). This compound layer has an underlying diffusion zone containing iron (and alloy) nitrides and absorbed nitrogen associated with it. The white layer has excellent wear and anti-scuffing properties and is produced with minimum distortion. The diffusion zone, provided it is substantial enough, improves fatigue properties such as endurance limit, especially in carbon and low-alloy steels. Some of the increased hardness of the case is due to a diffusion zone beneath the compound layer, especially in the more highly alloyed steels with strong nitride formers.

It is not uncommon to observe porosity of the compound layer due to the presence of a carburizing reaction at the steel surface, which influences the nitriding kinetics and therefore the degree and type of porosity at the surface of the epsilon (e) layer. Three different types of layers can be produced: no porosity, sponge porosity or columnar porosity. Some applications require deep nonporous epsilon layers. Others applications where, for example, optimum corrosion resistance is needed benefit from the presence of sponge porosity. Still others benefit from columnar porosity, where oil retention can enhance wear resistance.

Austenitic Nitrocarburizing (ANC)

A lower-temperature variant of carbonitriding is austenitic nitrocarburizing. This process takes place in the temperature range of 675-775°C (1250-1425°F). It can be controlled to produce a surface compound layer of epsilon (e) carbonitride with a subsurface of bainite and/or martensite produced on quenching, resulting in a good support structure for the hard surface. The microstructure is particularly useful in intermediate stress-point contact-resistance applications (e.g., helical gears).

Summary

Understanding these processes better allows each heat-treatment method to be used to its best advantage.

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